EXHIBIT M

Exhibit A-31
Invalidity Claim Chart for U.S. Patent No. 7,924,802 vs. IEEE Std. 802.11-2007

IEEE Standard 802.11-2007 ("802.11-2007") was completed in March 2007 and published in June 2007. 802.11-2007 anticipates asserted claims 1–4, 6–10, 13, 14, 17, and 21–24 of U.S. Patent No. 7,924,802 ("the '802 Patent") under 35 U.S.C. § 102. 802.11-2007 also renders obvious asserted claims 1–4, 6–10, 13, 14, 17, and 21–24 of the '802 Patent under 35 U.S.C. § 103, alone based on the state of the art and/or in combination with one or more other references identified in Exs. A-1–A-31, Cover Pleading, and First Supplemental Ex. A-Obviousness Chart.[1]

To the extent Plaintiff alleges that 802.11-2007 does not disclose any particular limitation of the asserted claims in the '802 Patent, either expressly or inherently, it would have been obvious to a person of ordinary skill in the art as of the priority date of the '802 Patent to modify 802.11-2007 and/or to combine the teachings of 802.11-2007 with other prior art references, including but not limited to the present prior art references found in Exs. A-1–A-31, Cover Pleading, First Supplemental Ex. A-Obviousness Chart, and the relevant section of charts for other prior art for the '802 Patent in a manner that would render the asserted claims of these patents invalid as obvious.

With respect to the obviousness of the asserted claims of the '802 Patent under 35 U.S.C. § 103, one or more of the principles enumerated by the United States Supreme Court in *KSR v. Teleflex*, 550 U.S. 398 (2007) apply, including: (a) combining various claimed elements known in the prior art according to known methods to yield a predictable result; and/or (b) making a simple substitution of one or more known elements for another to obtain a predictable result; and/or (c) using a known technique to improve a similar device or method in the same way; and/or (d) applying a known technique to a known device or method ready for improvement to yield a predictable result; and/or (e) choosing from a finite number of identified, predictable solutions with a reasonable expectation of success or, in other words, the solution was one which was "obvious to try"; and/or (f) a known work in one field of endeavor prompting variations of it for use either in the same field or a different field based on given design incentives or other market forces in which the variations were predictable to one of ordinary skill in the art; and/or (g) a teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill in the art to modify the prior art reference or to combine the

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[1] Samsung is investigating this prior art and has not yet completed discovery from third parties, who may have relevant information concerning the prior art, and therefore, Samsung reserves the right to supplement this chart after additional discovery is received. To the extent that any of the prior art discloses the same or similar functionality or feature(s) of any of the accused products, Samsung reserves the right to argue that said feature or functionality does not practice any limitation of any of the asserted claims, and to argue, in the alternative, that if said feature or functionality is found to practice any limitation of any of the asserted claims in the '802 Patent, then the prior art reference teaches the limitation and that the claim is not patentable.

teachings of various prior art references to arrive at the claimed invention. It therefore would have been obvious to one of ordinary skill in the art to combine the disclosures of these references in accordance with the principles and rationales set forth above.

The citations to portions of any reference in this chart are exemplary only. For example, a citation that refers to or discusses a figure or figure item should be understood to also incorporate by reference that figure and any additional descriptions of that figure as if set forth fully therein. Samsung reserves the right to rely on the entirety of the references cited in this chart to show that the asserted claims of the ’802 Patent are invalid. Citations presented for one claim limitation are expressly incorporated by reference into all other limitations for that claim as well as all limitations of all claims on which that claim depends. Samsung also reserves the right to rely on additional citations or sources of evidence that also may be applicable, or that may become applicable in light of claim construction, changes in Plaintiff’s infringement contentions, and/or information obtained during discovery as the case progresses.

Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
[1.1] A method of transmitting information in a wireless communication channel comprising:	To the extent the preamble is limiting, 802.11-2007 discloses “A method of transmitting information in a wireless communication channel comprising.” See, e.g.:

<table>
<tr><th>Claim 1 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

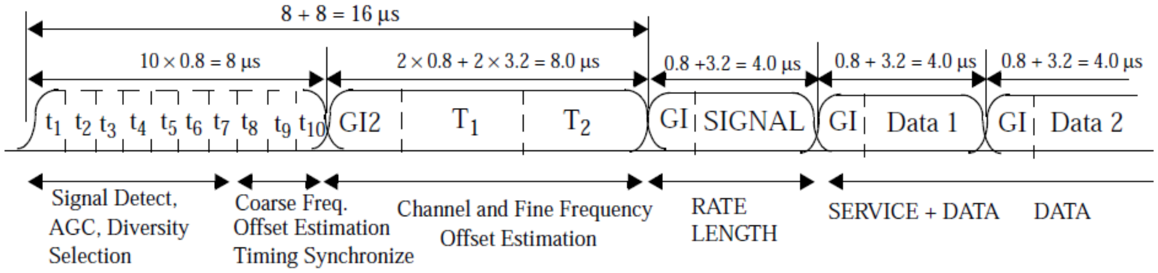
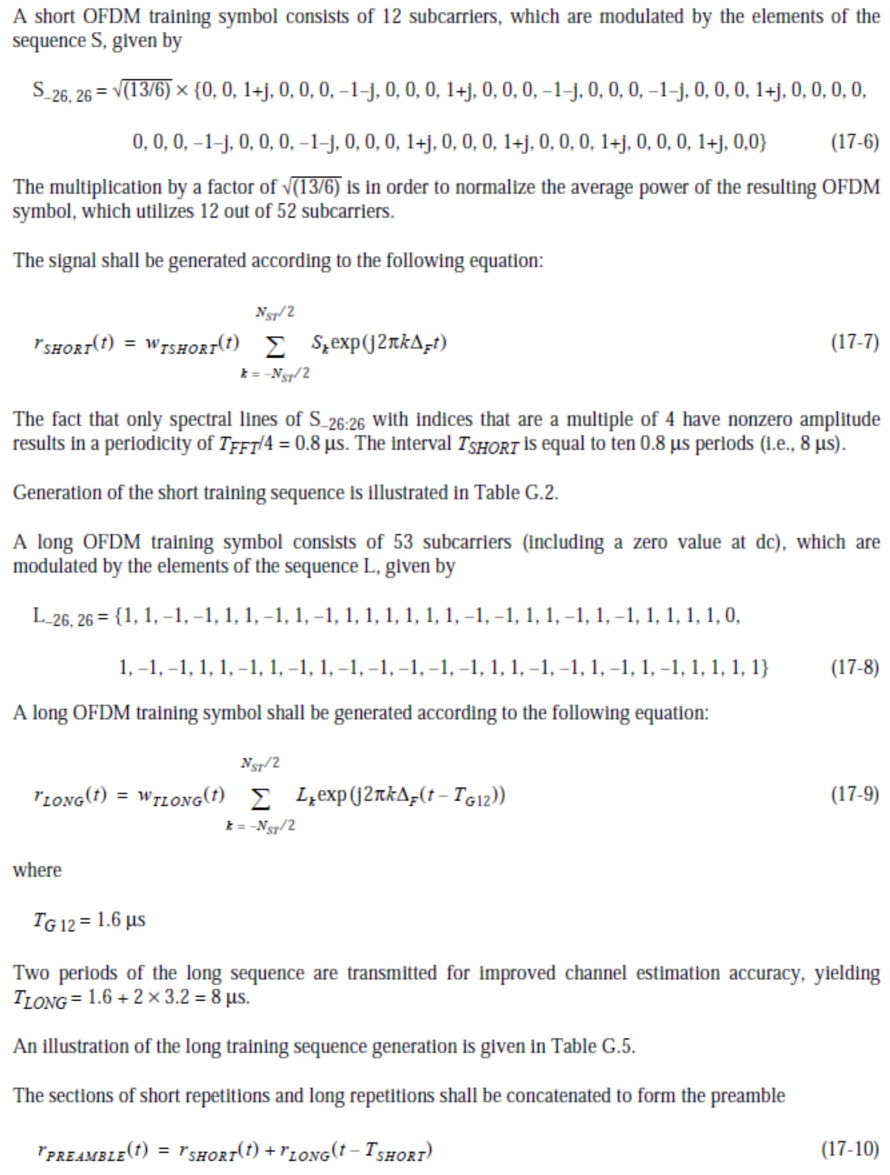


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

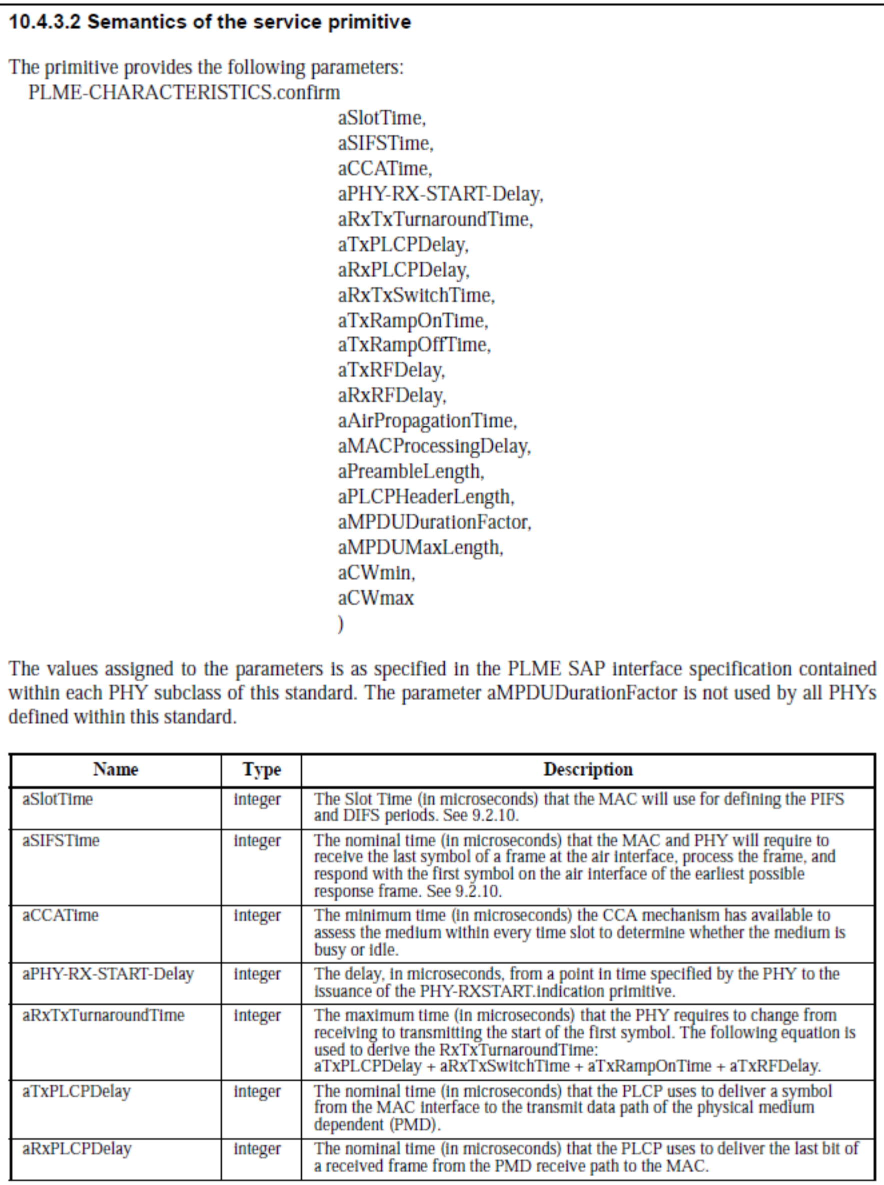
See, e.g., 802.11-2007 § 17.3.3

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[1.2] transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency; and	802.11-2007 discloses “transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts**

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



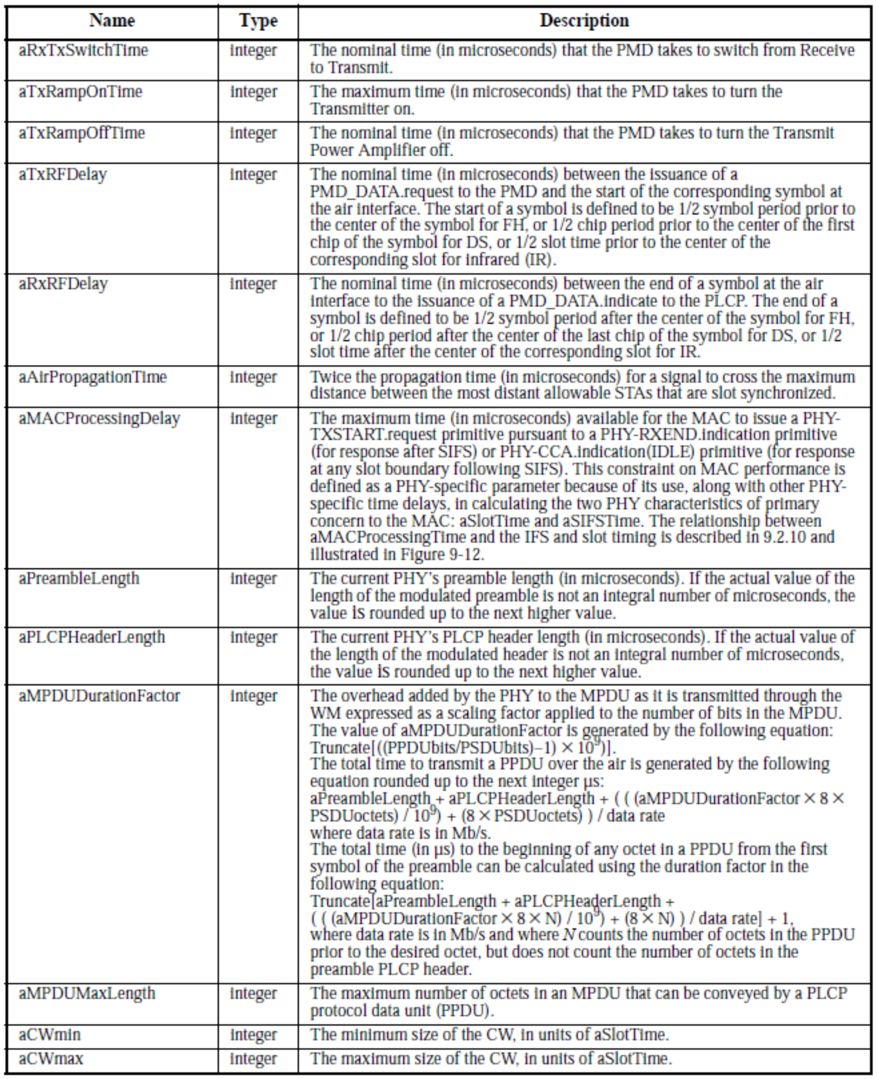
10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

<table>
<tr><th>Claim 1 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Name</th><th>Type</th><th>Description</th></tr>
<tr><td>aRxTxSwitchTime</td><td>integer</td><td>The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.</td></tr>
<tr><td>aTxRampOnTime</td><td>integer</td><td>The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.</td></tr>
<tr><td>aTxRampOffTime</td><td>integer</td><td>The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.</td></tr>
<tr><td>aTxRFDelay</td><td>integer</td><td>The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).</td></tr>
<tr><td>aRxRFDelay</td><td>integer</td><td>The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.</td></tr>
<tr><td>aAirPropagationTime</td><td>integer</td><td>Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.</td></tr>
<tr><td>aMACProcessingDelay</td><td>integer</td><td>The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.</td></tr>
<tr><td>aPreambleLength</td><td>integer</td><td>The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.</td></tr>
<tr><td>aPLCPHeaderLength</td><td>integer</td><td>The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.</td></tr>
<tr><td>aMPDUDurationFactor</td><td>integer</td><td>The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU.
The value of aMPDUDurationFactor is generated by the following equation:
$\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$.
The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs:
$\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$
where data rate is in Mb/s.
The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation:
$\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$,
where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.</td></tr>
<tr><td>aMPDUMaxLength</td><td>integer</td><td>The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).</td></tr>
<tr><td>aCWmin</td><td>integer</td><td>The minimum size of the CW, in units of aSlotTime.</td></tr>
<tr><td>aCWmax</td><td>integer</td><td>The maximum size of the CW, in units of aSlotTime.</td></tr>
</table>

See, e.g., 802.11-2007 § 10.4.3.2
</td></tr>
</table>

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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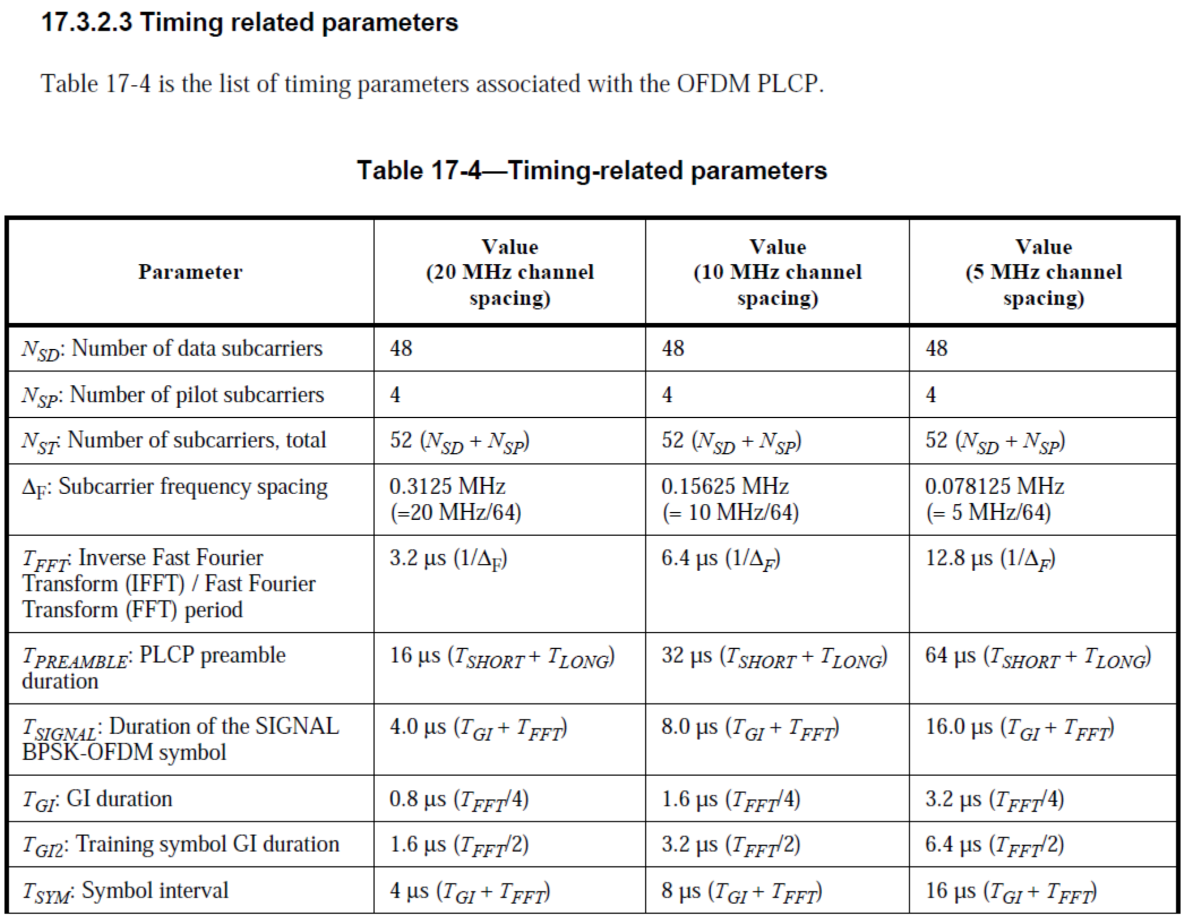
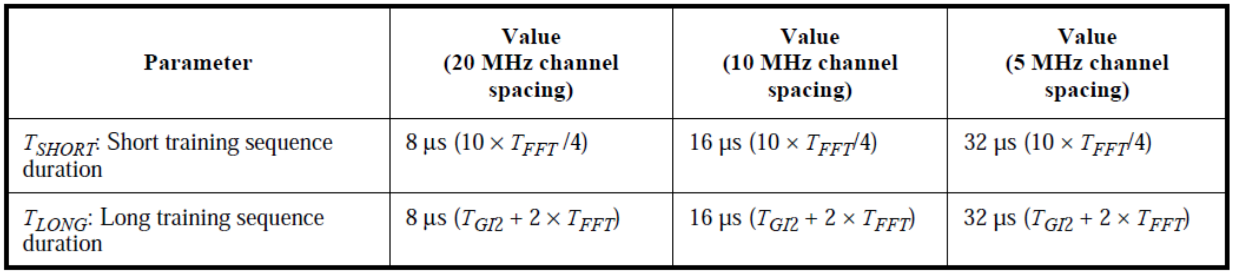


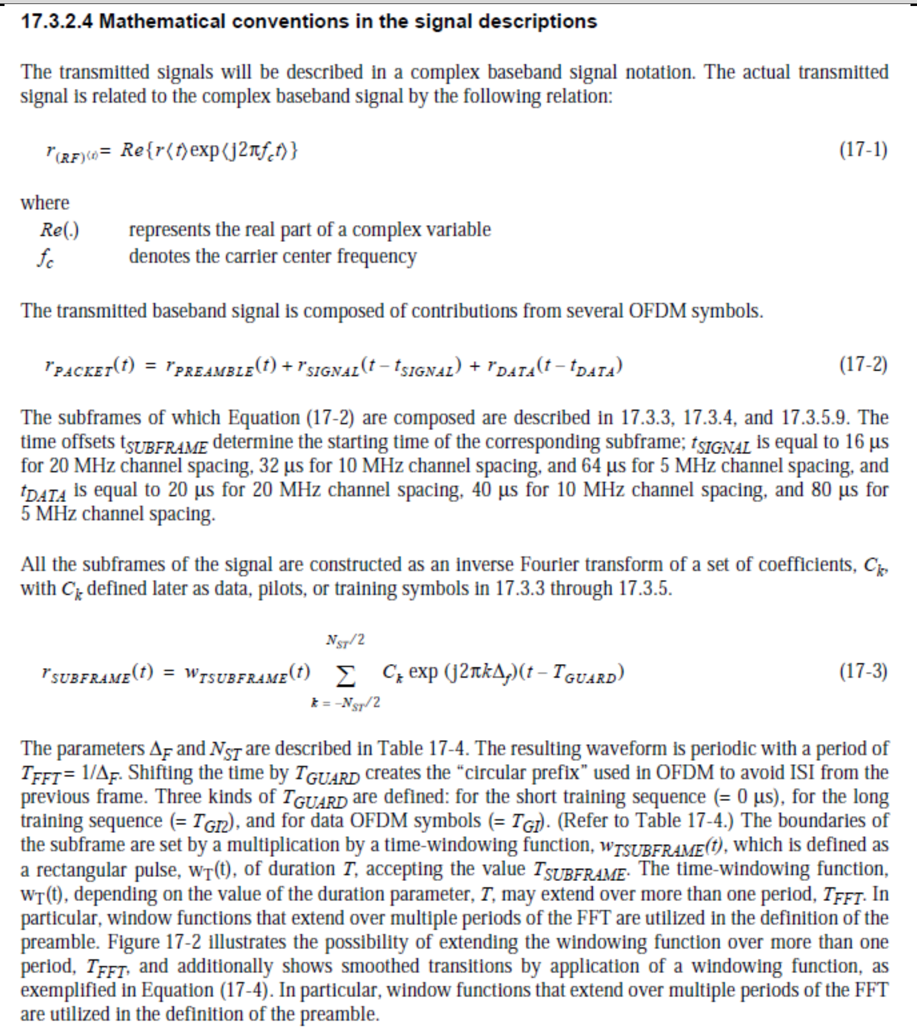
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 1 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

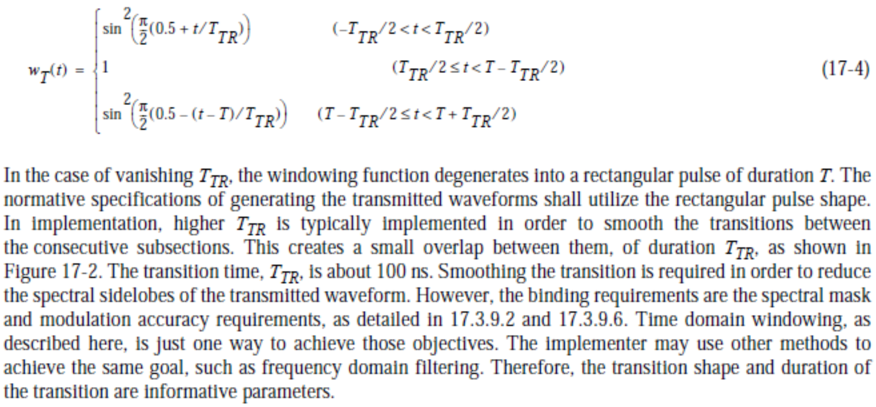
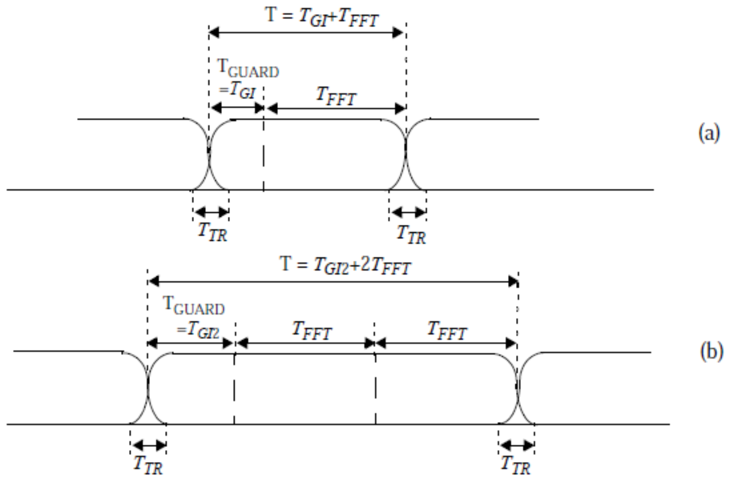
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

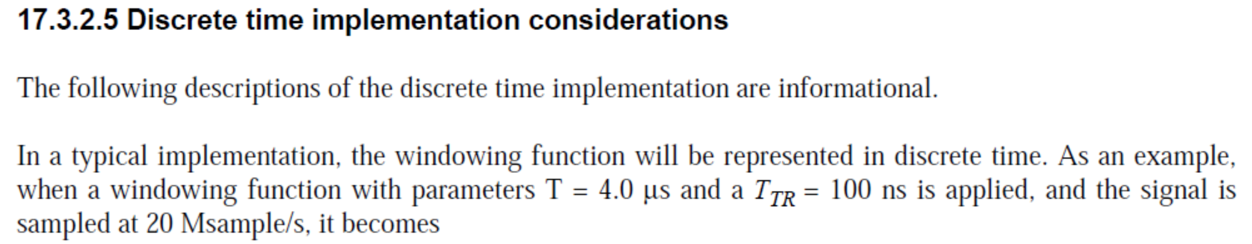
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

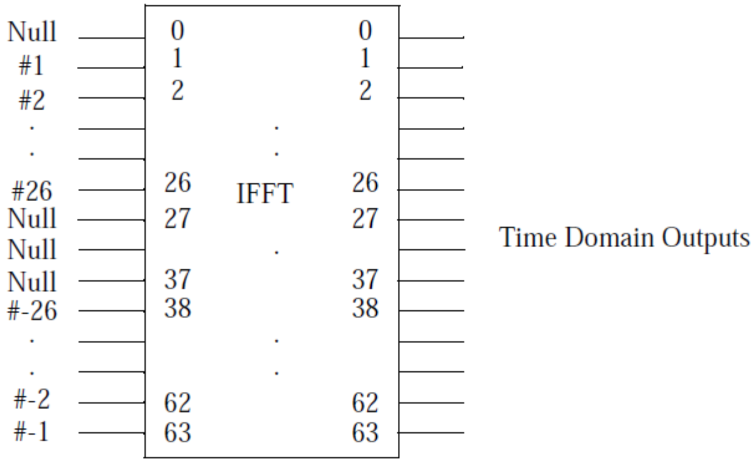
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

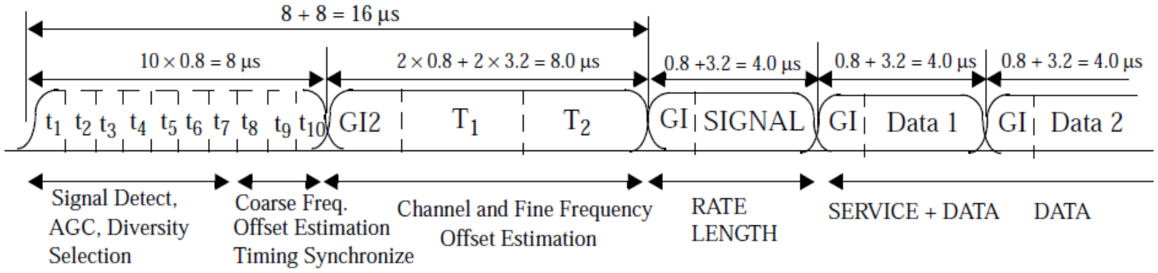
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

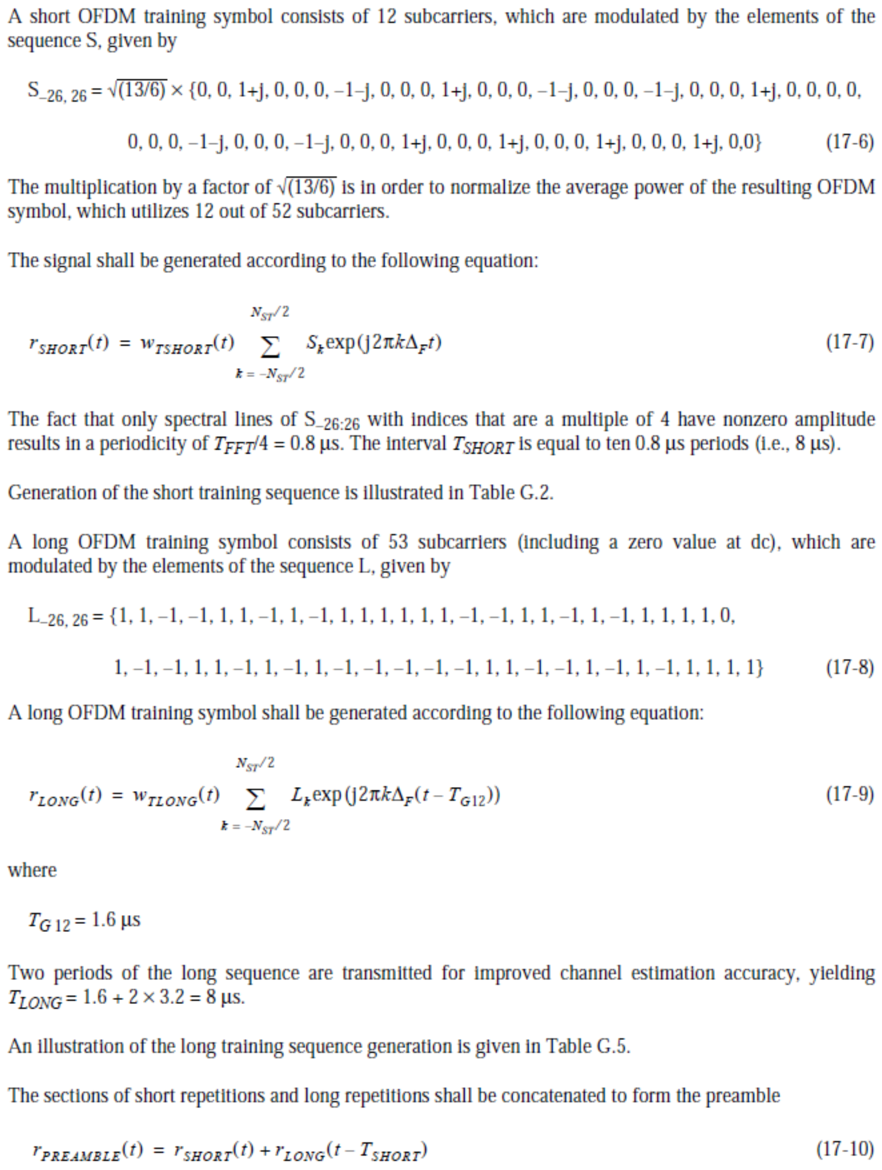
The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ (17-4) In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 1 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	$$w_T[n] = w_T(nT_S) = \left\{\begin{matrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{matrix}\right\} \qquad (17\text{-}5)$$ The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

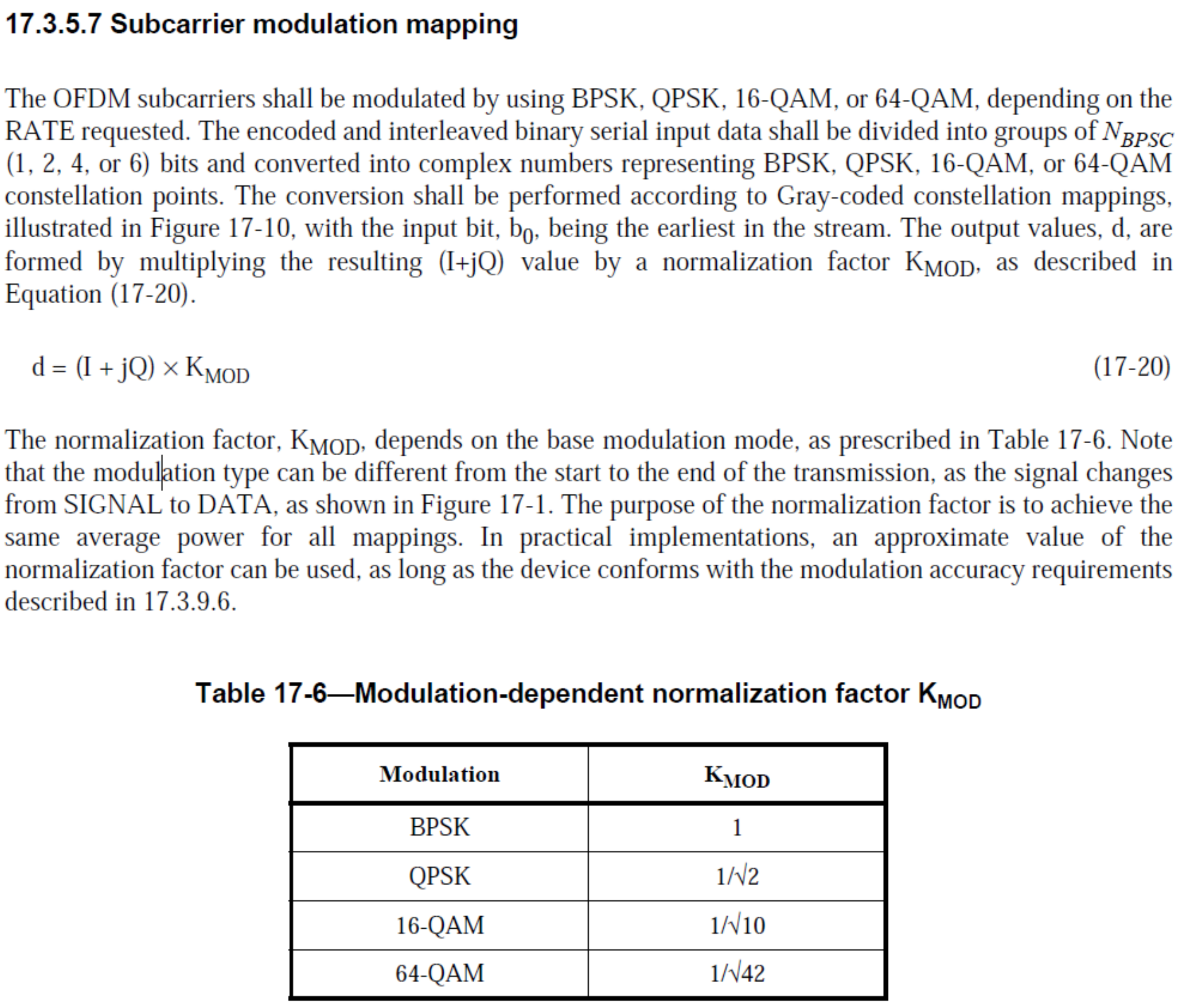
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 1 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$
\begin{aligned}
p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\
&1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\
&-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\
&-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\}
\end{aligned}
\qquad (17\text{-}25)
$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

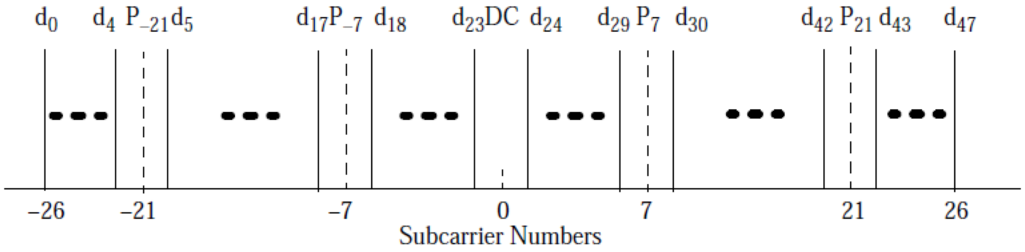


Figure 17-11—Subcarrier frequency allocation

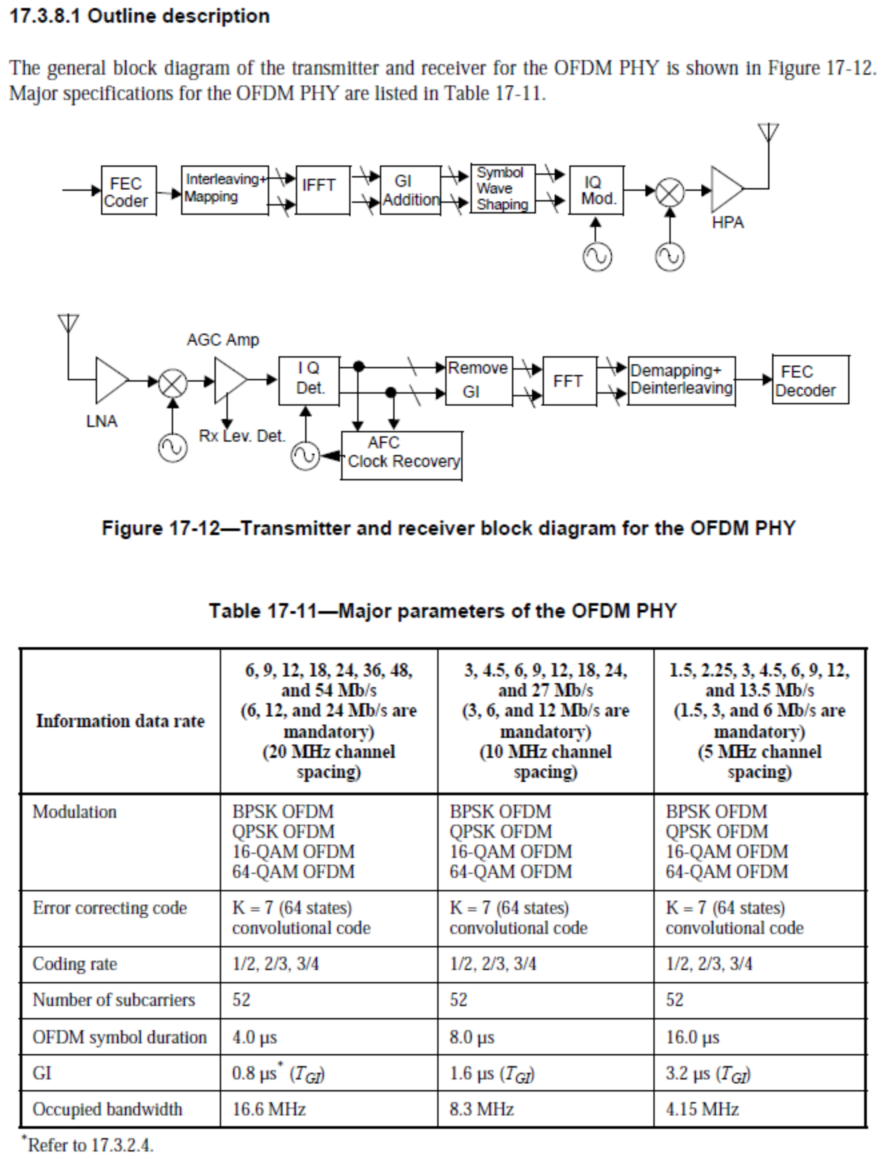
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

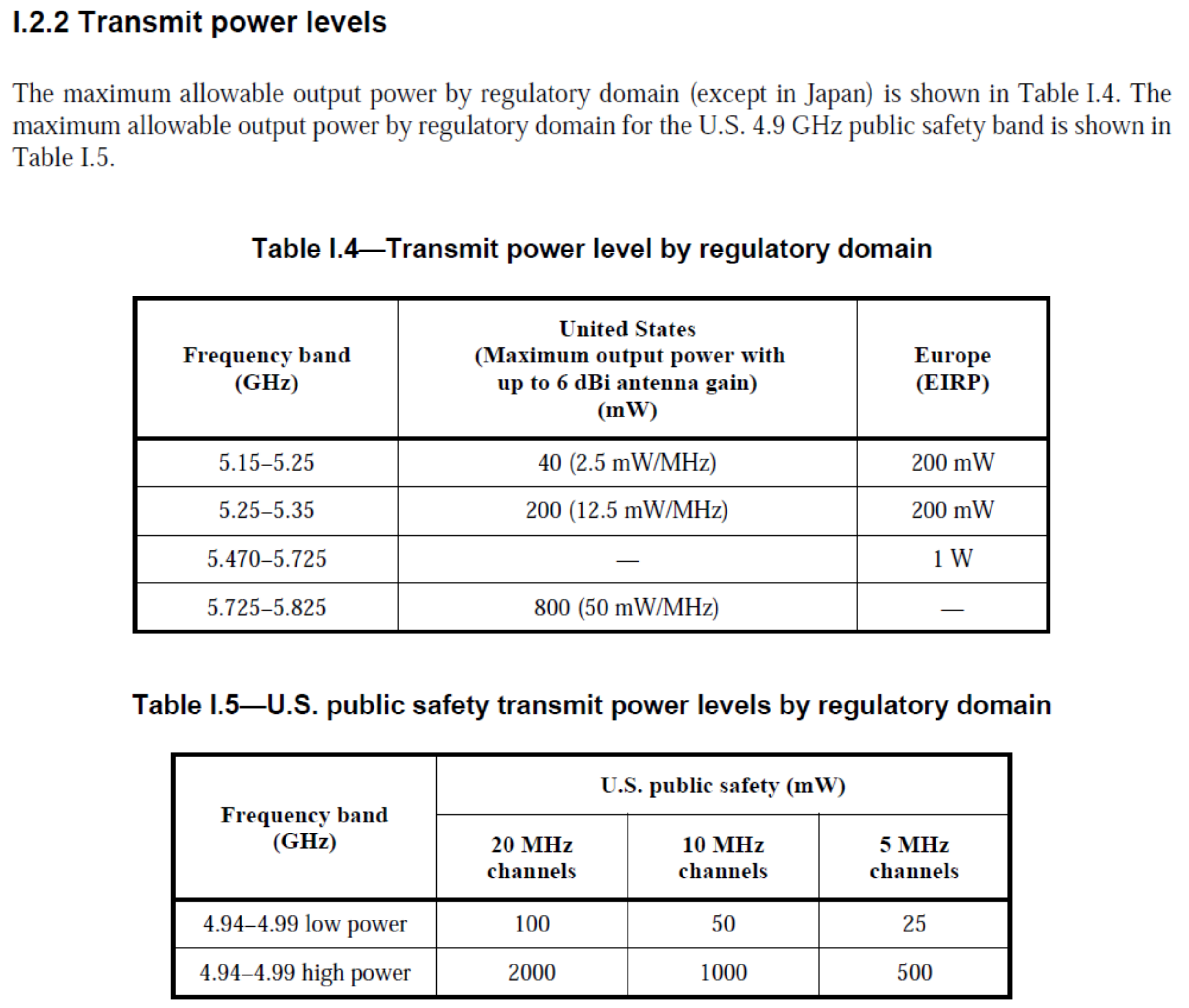
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § I.2.2



I.2.2 Transmit power levels

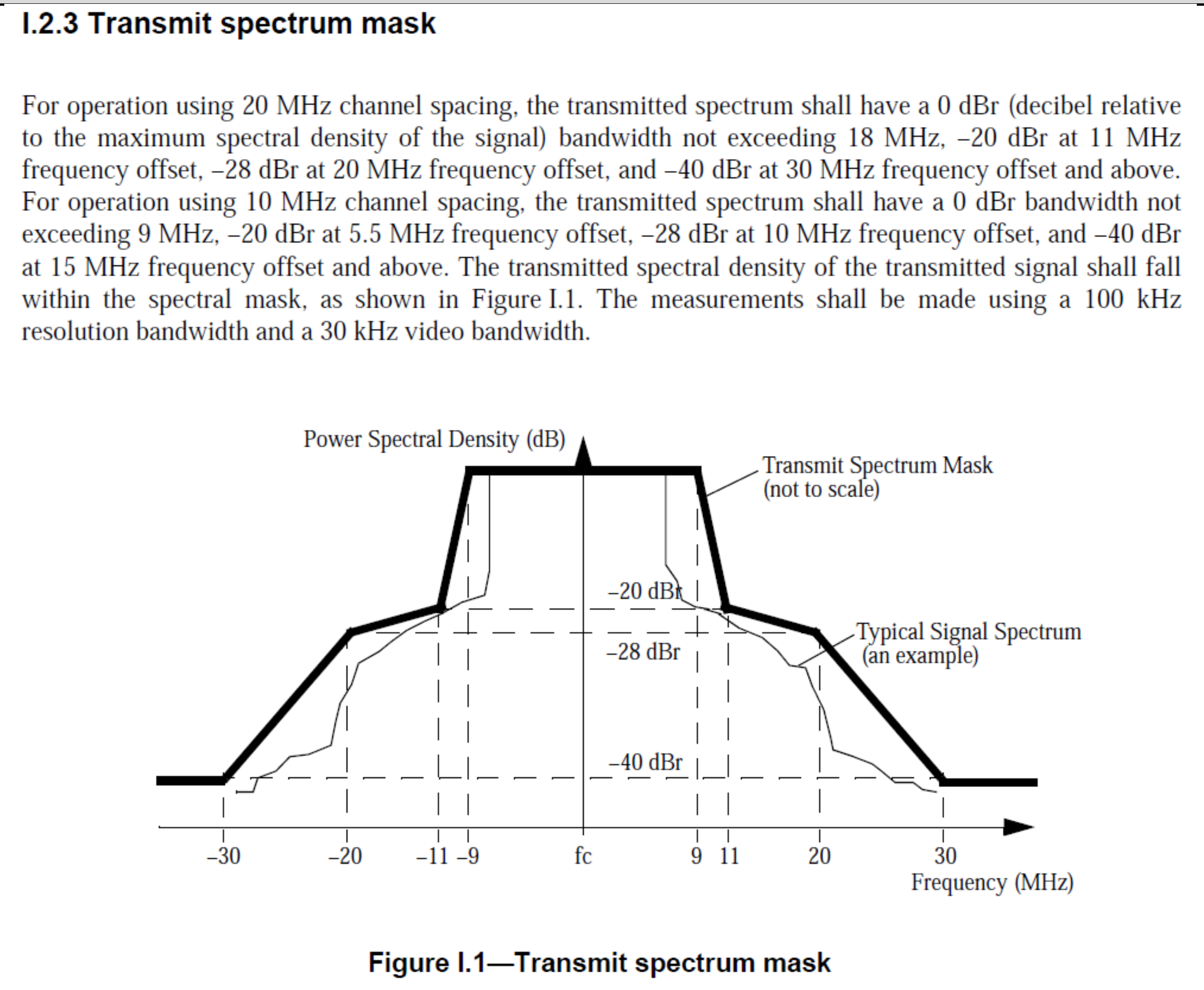
The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

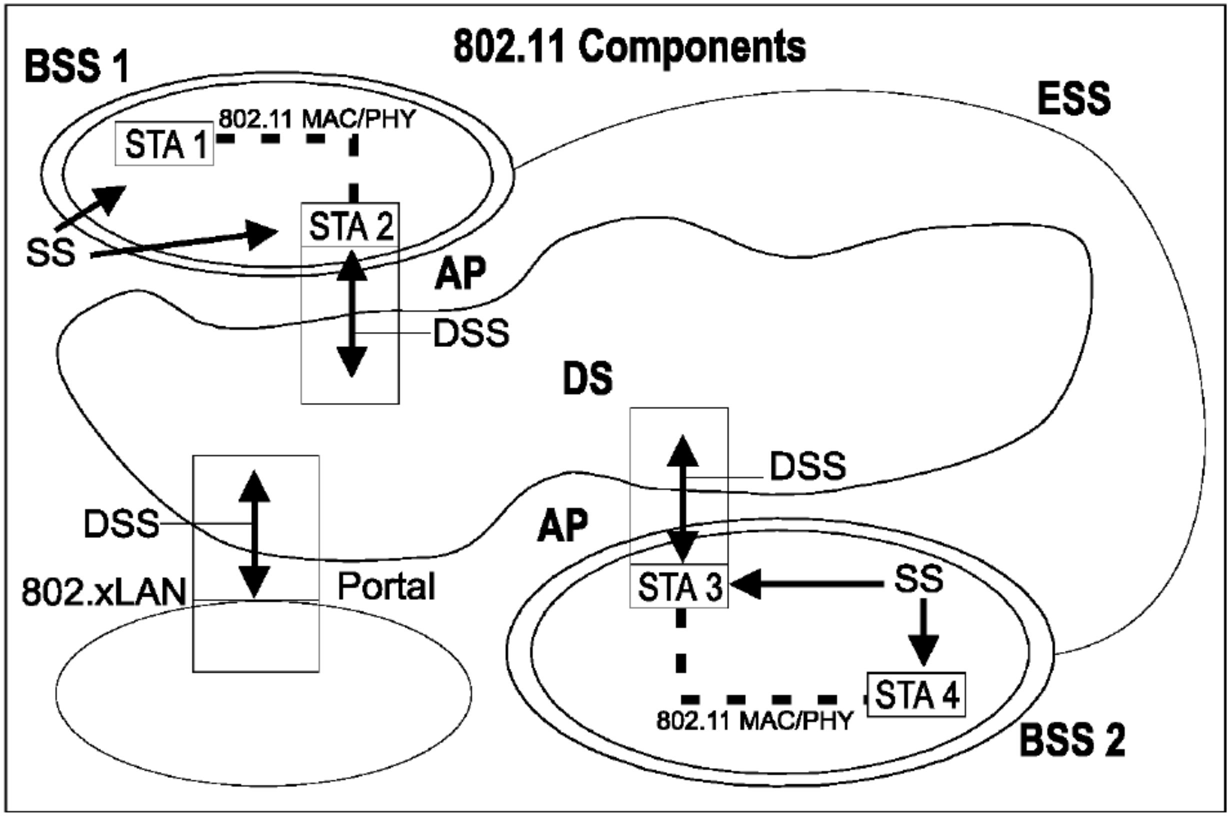
Table I.4—Transmit power level by regulatory domain

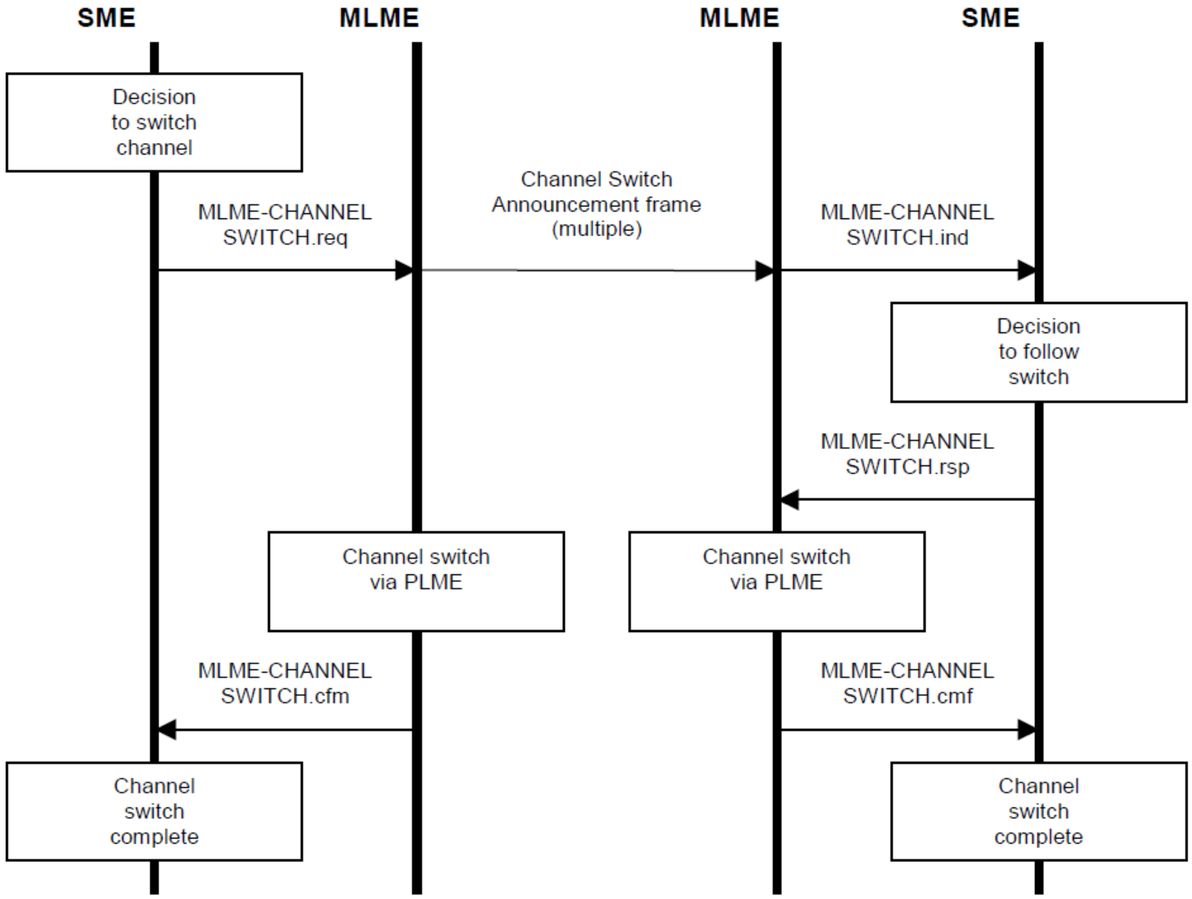
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

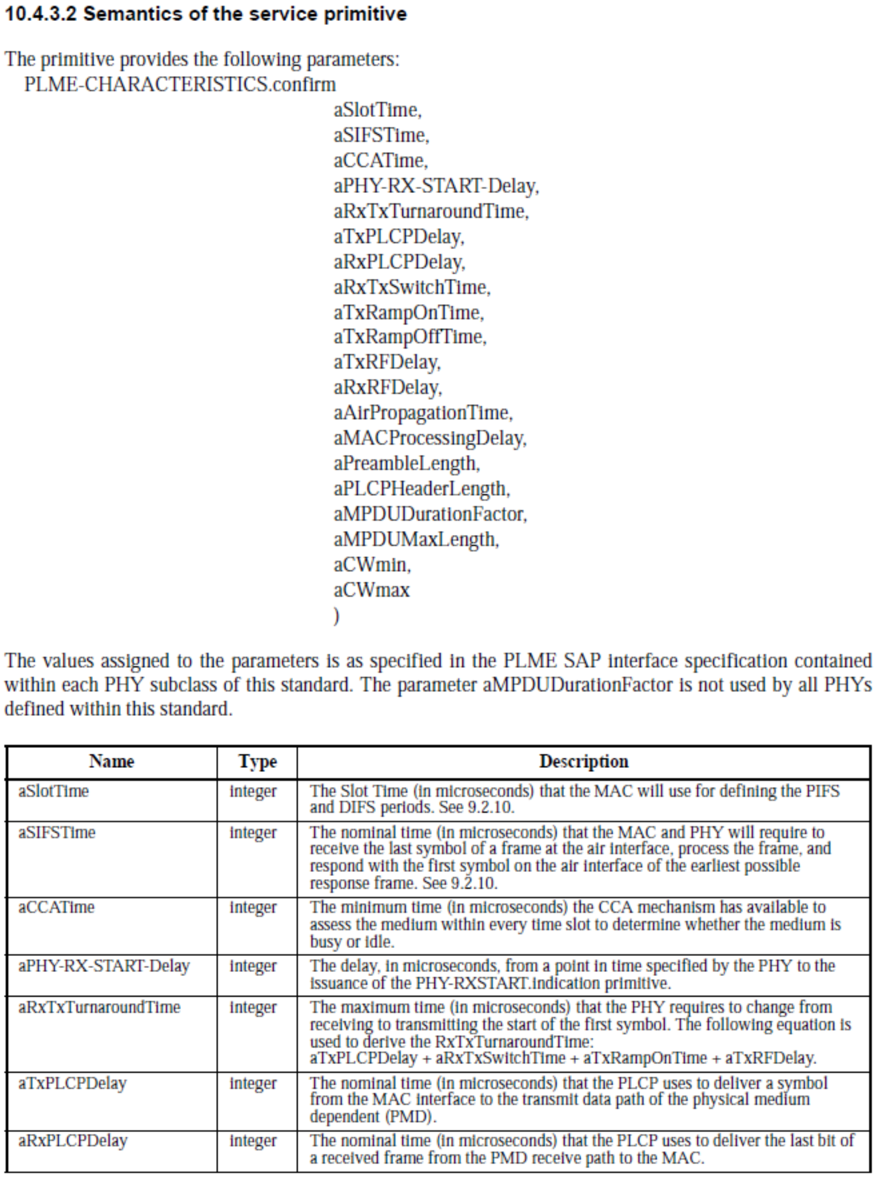
Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[1.3] simultaneously transmitting second information across a second frequency range using the same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency.	802.11-2007 discloses “simultaneously transmitting second information across a second frequency range using the same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

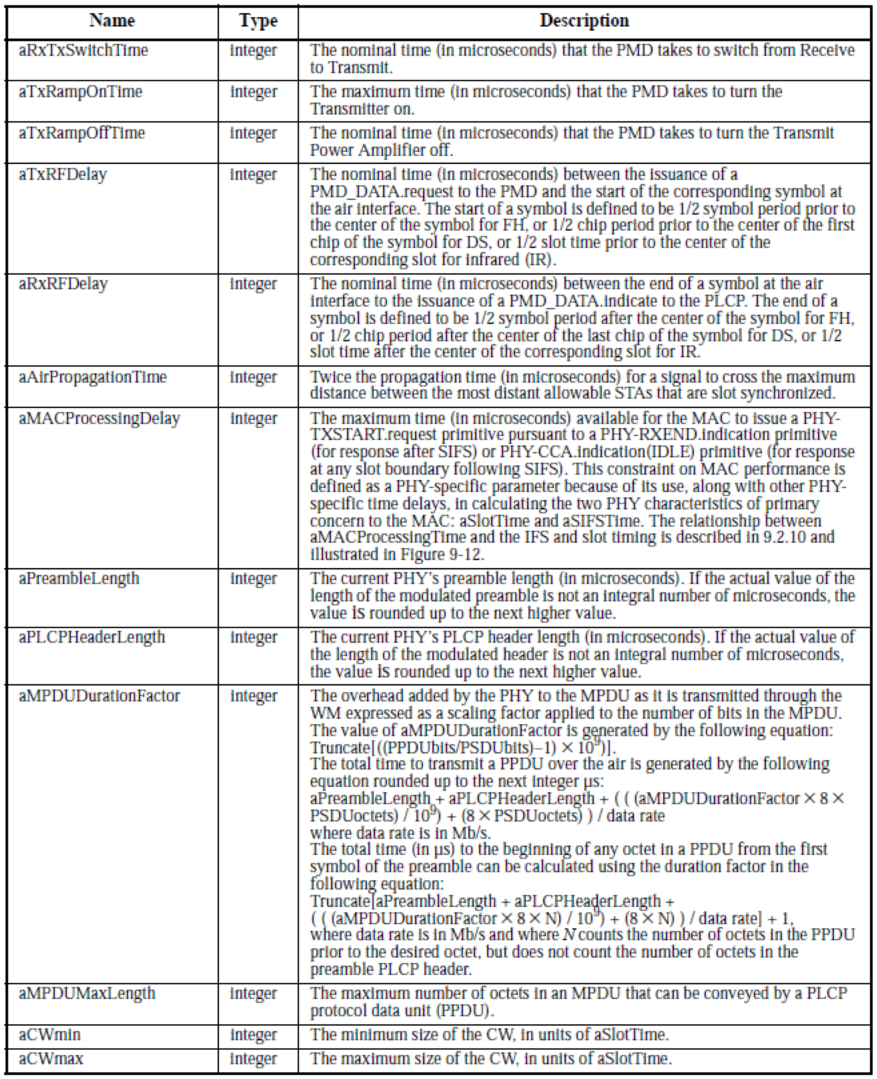
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 1 of the '802 Patent	**Prior Art Reference – 802.11-2007**

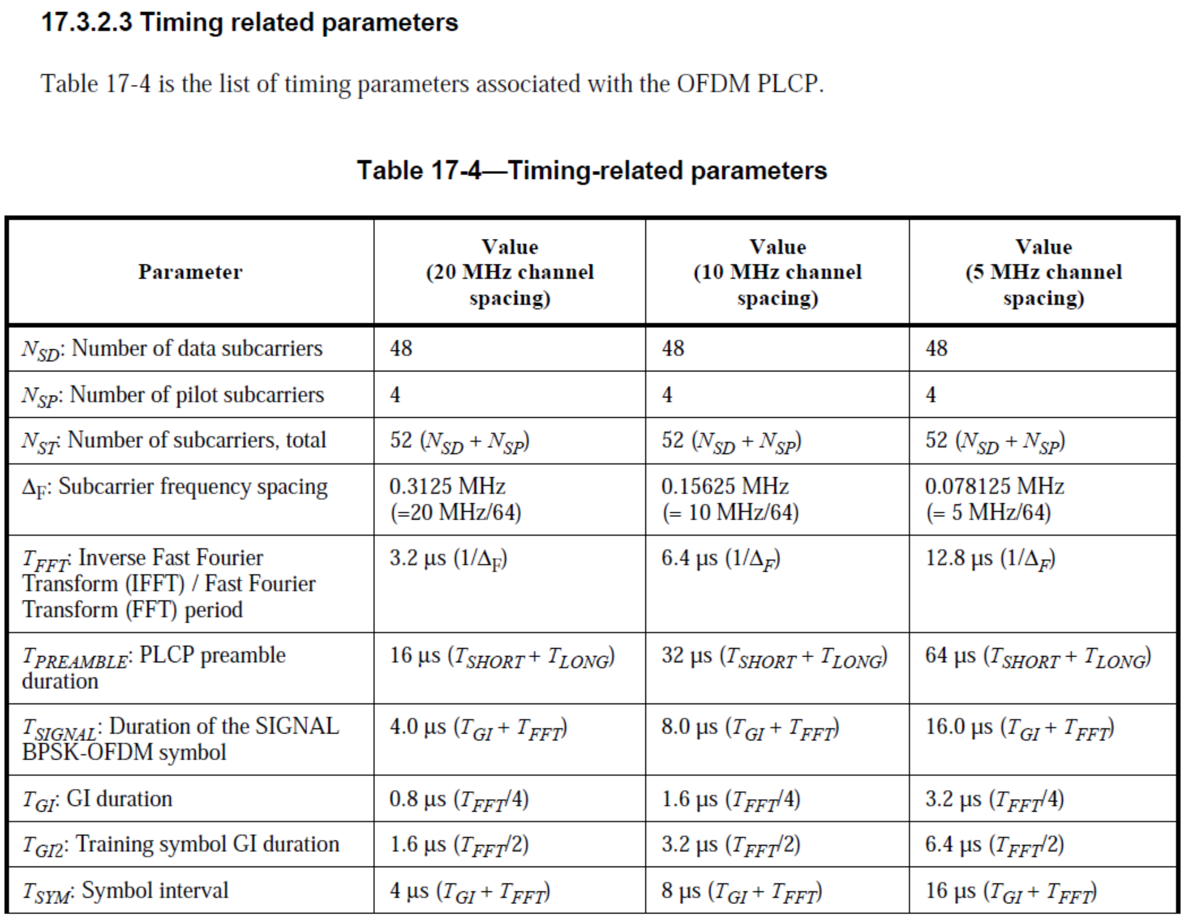


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

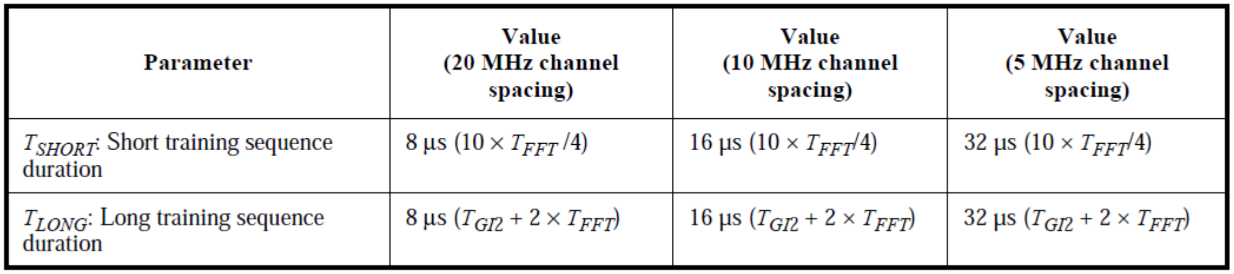
Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.2.3 Timing related parameters

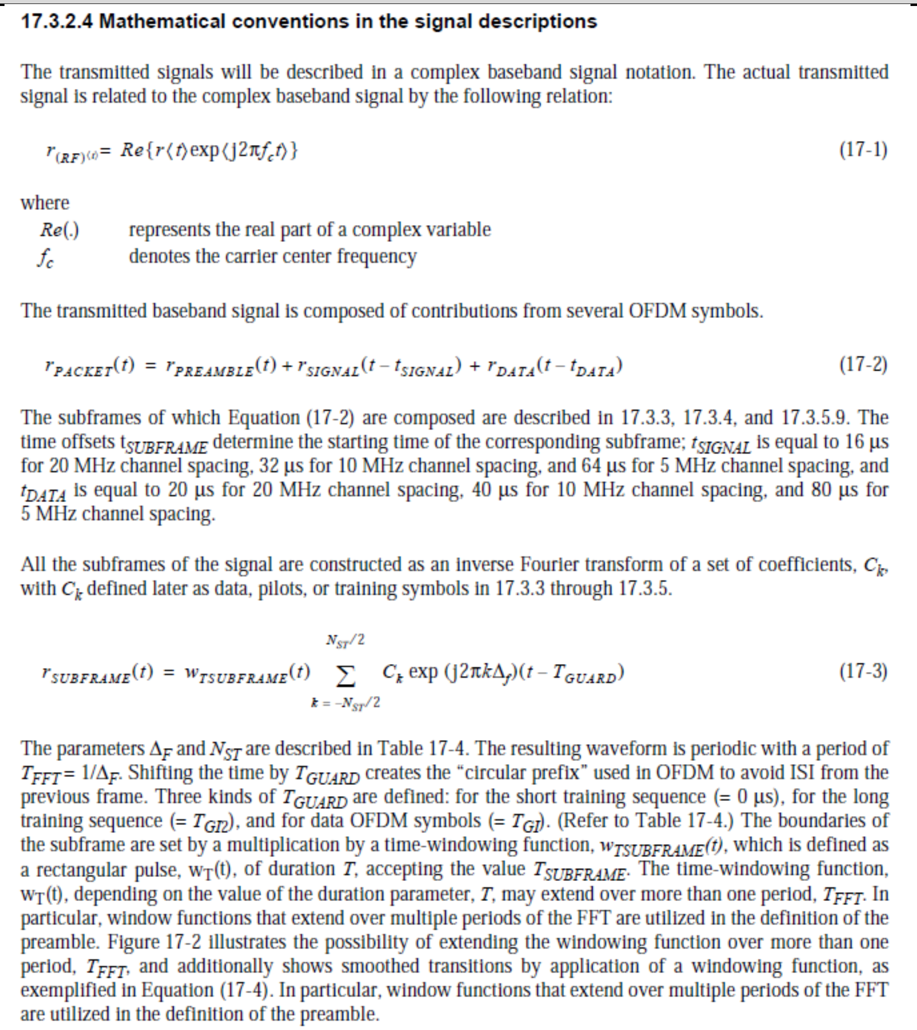
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 1 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

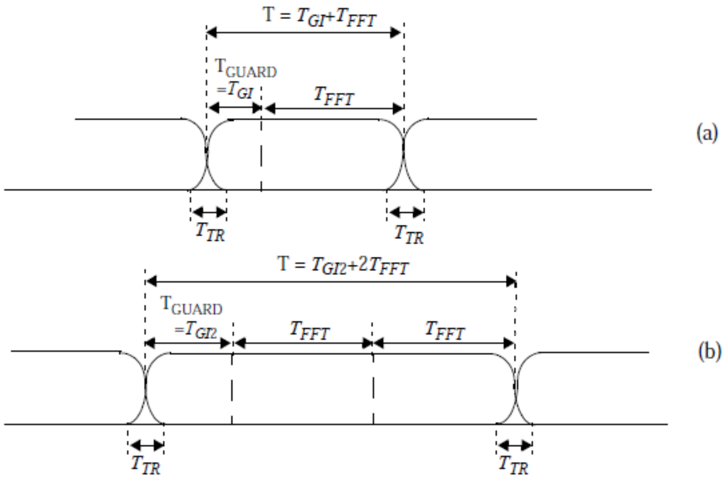
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

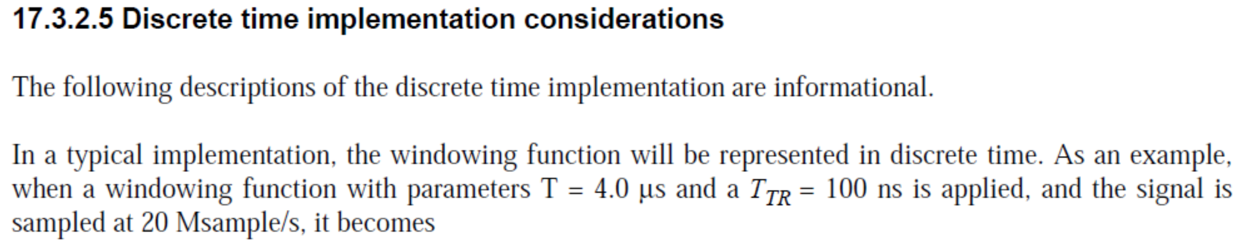
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

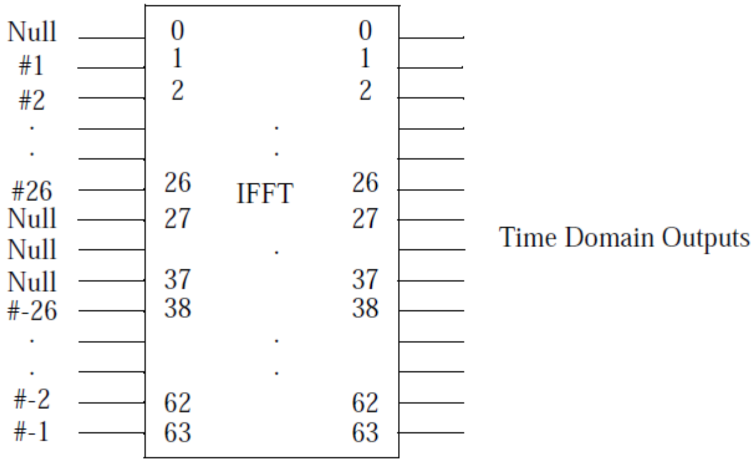
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 1 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \quad (17\text{-}5)$ The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 1 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

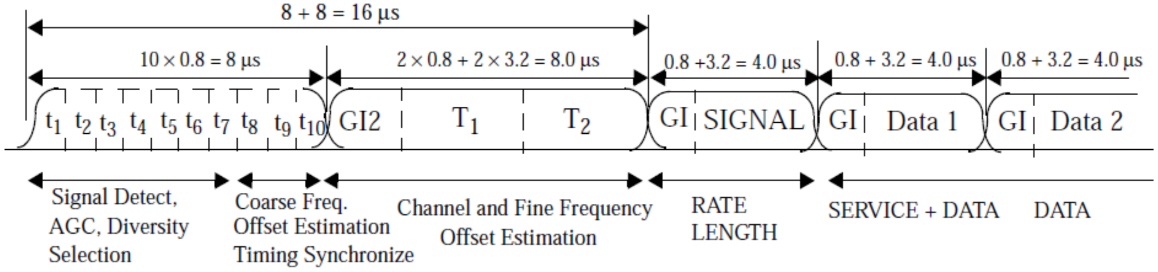
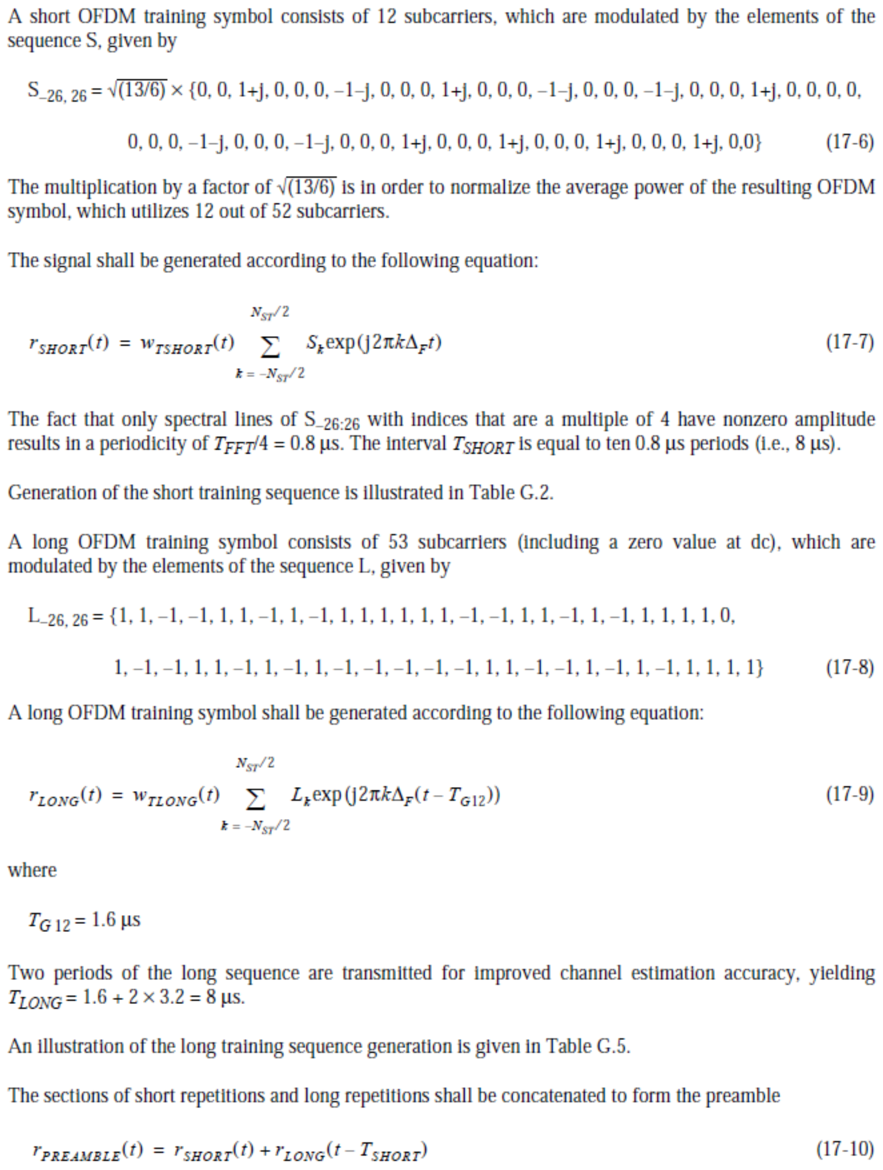


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1{+}j, 0, 0, 0, -1{-}j, 0, 0, 0, 1{+}j, 0, 0, 0, -1{-}j, 0, 0, 0, -1{-}j, 0, 0, 0, 1{+}j, 0, 0, 0, 0,$$

$$0, 0, 0, -1{-}j, 0, 0, 0, -1{-}j, 0, 0, 0, 1{+}j, 0, 0, 0, 1{+}j, 0, 0, 0, 1{+}j, 0, 0, 0, 1{+}j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

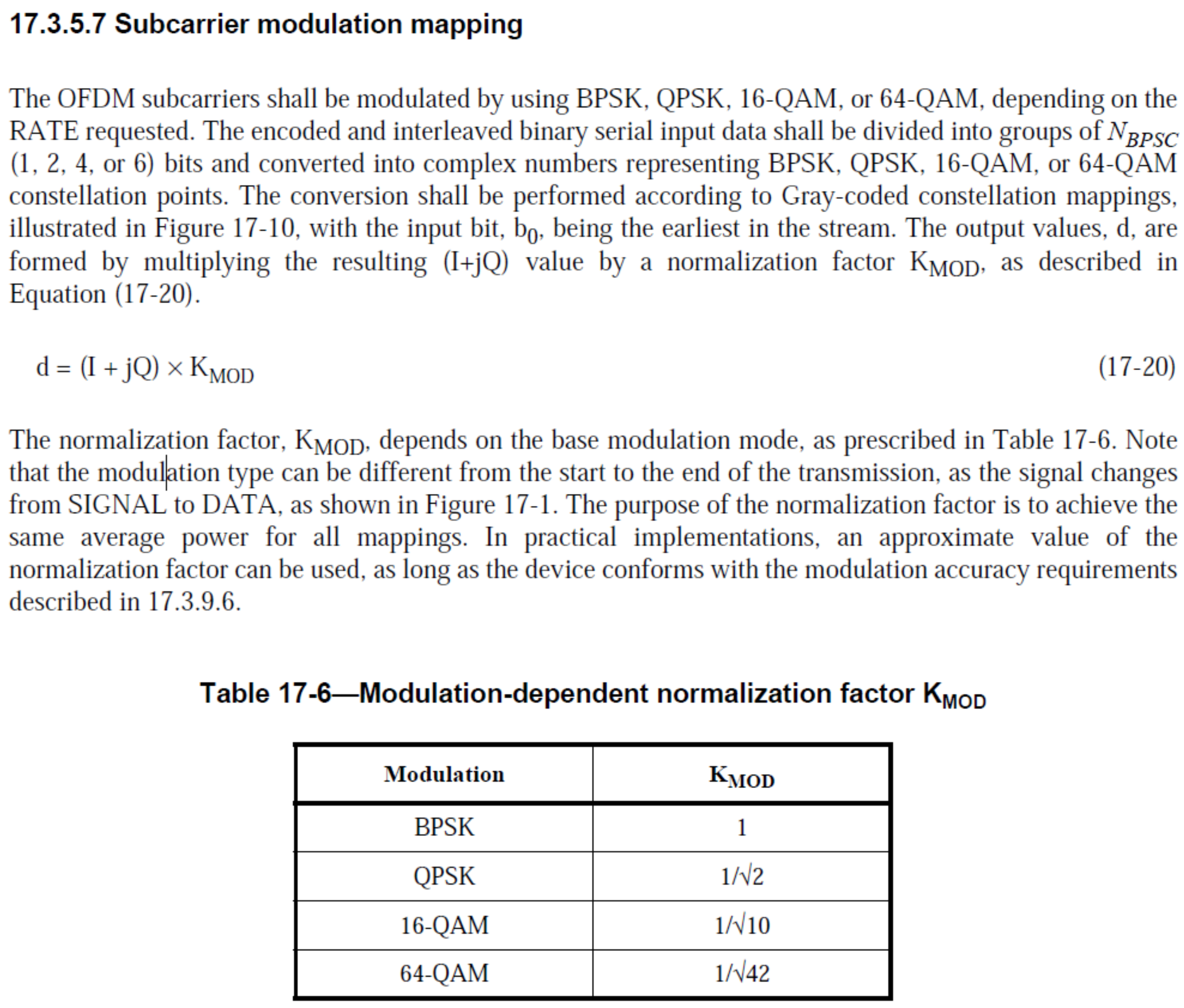
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 1 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \qquad (17\text{-}21)$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \qquad (17\text{-}22)$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \qquad (17\text{-}23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0,\\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \qquad (17\text{-}24)$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

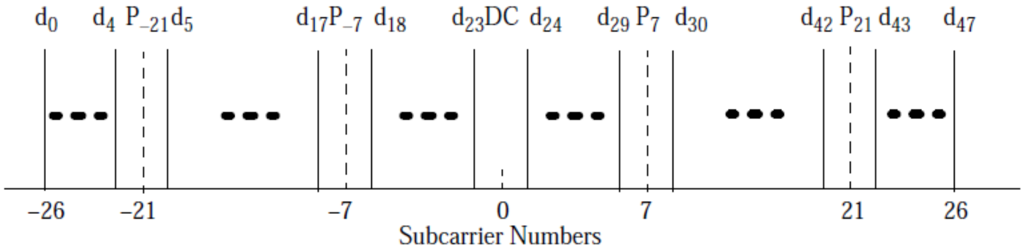


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

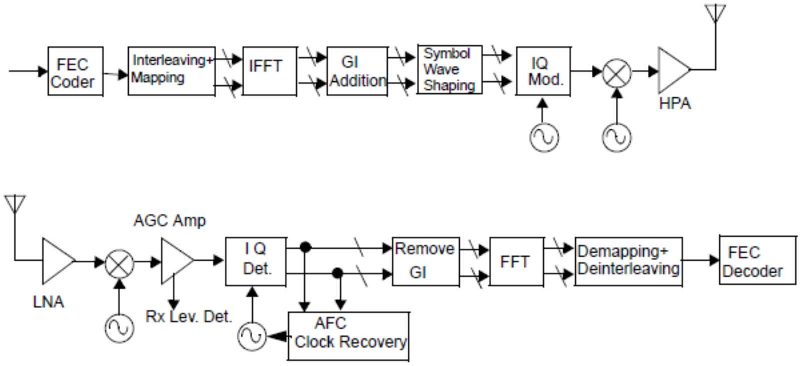


Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

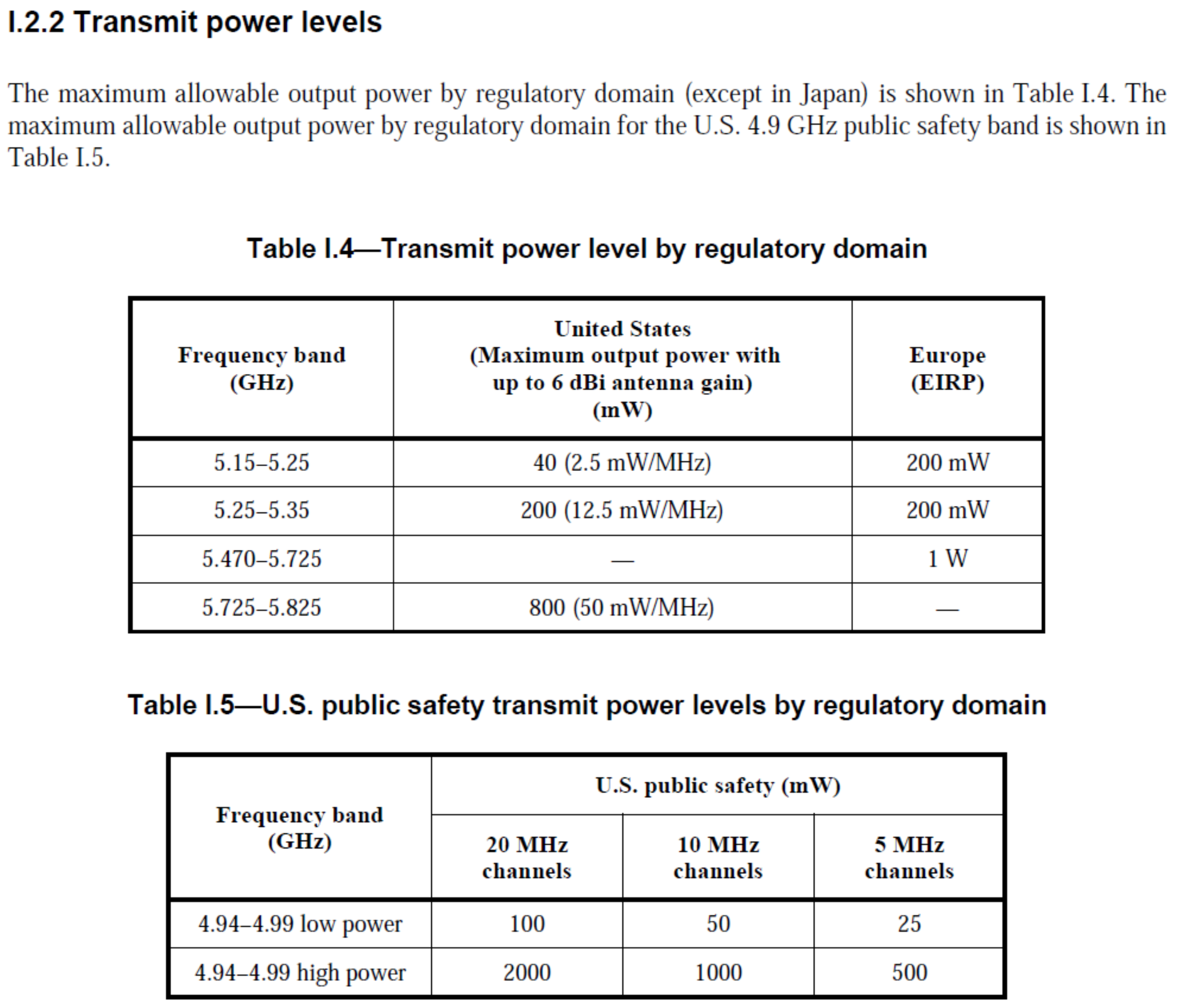
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

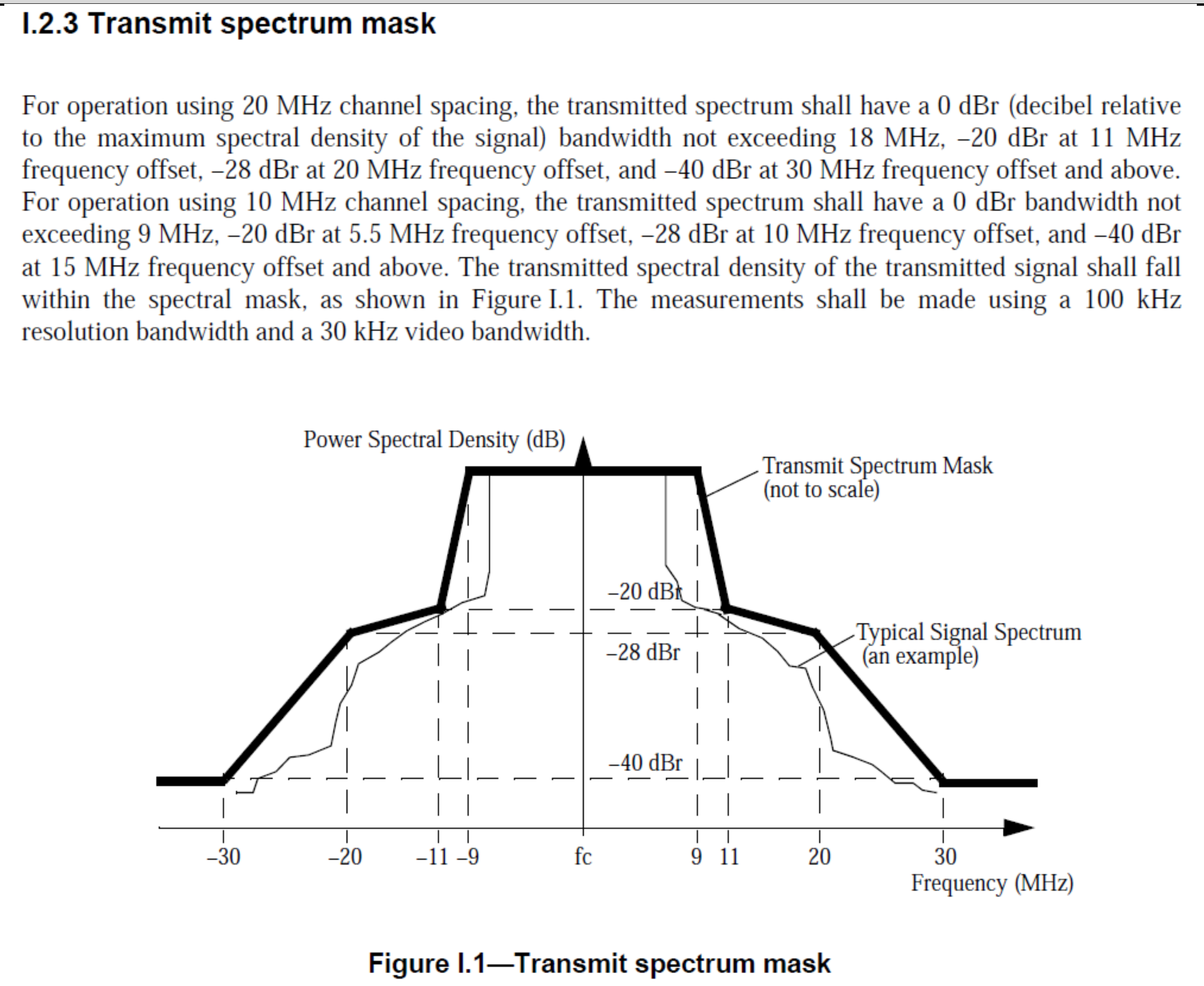
Table I.4—Transmit power level by regulatory domain

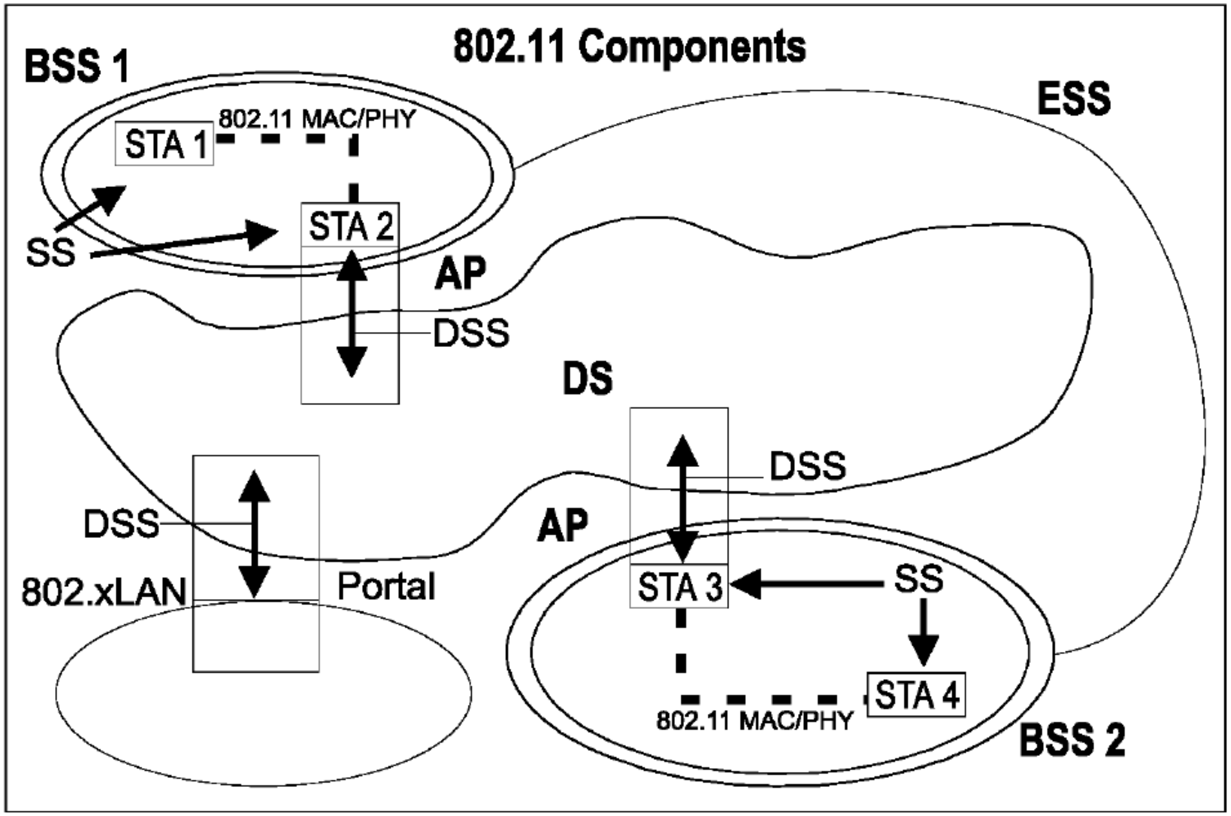
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

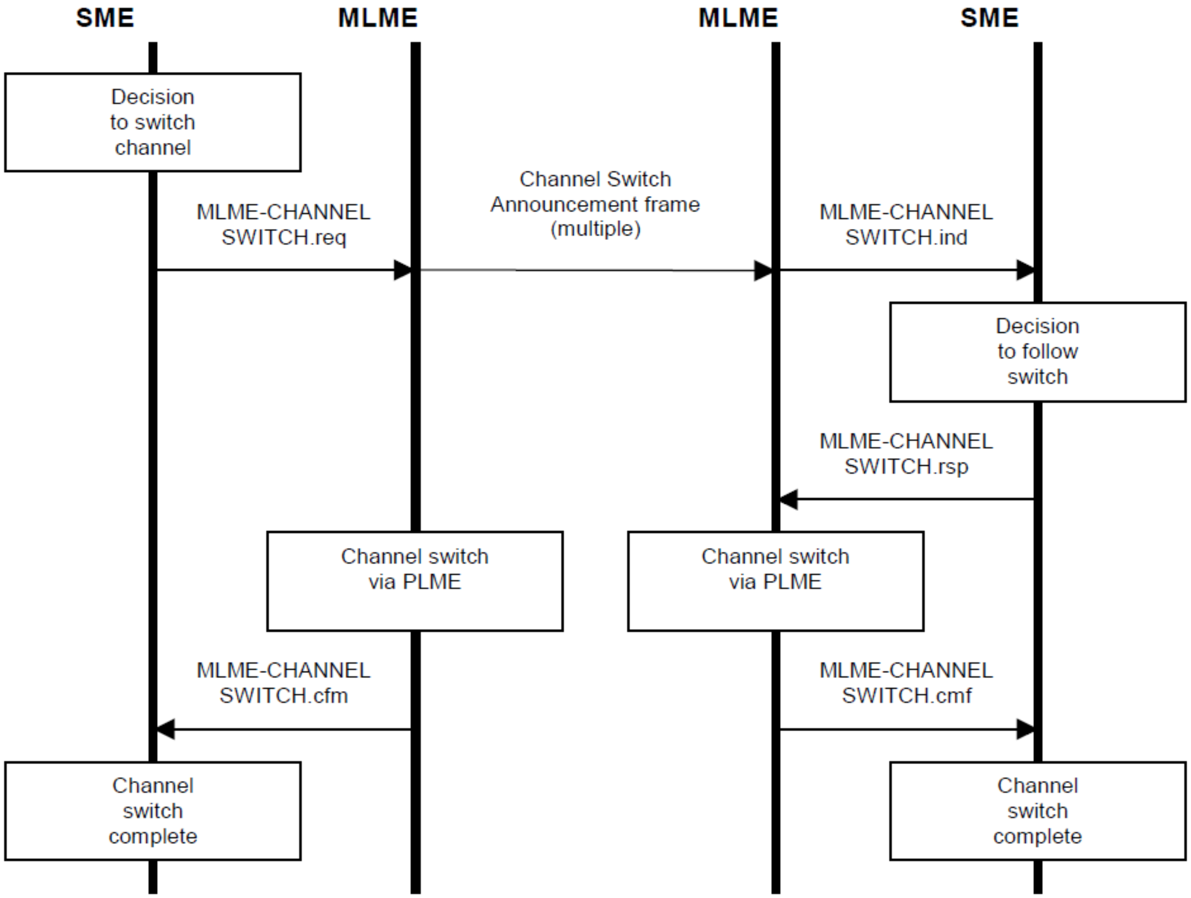
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 1 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

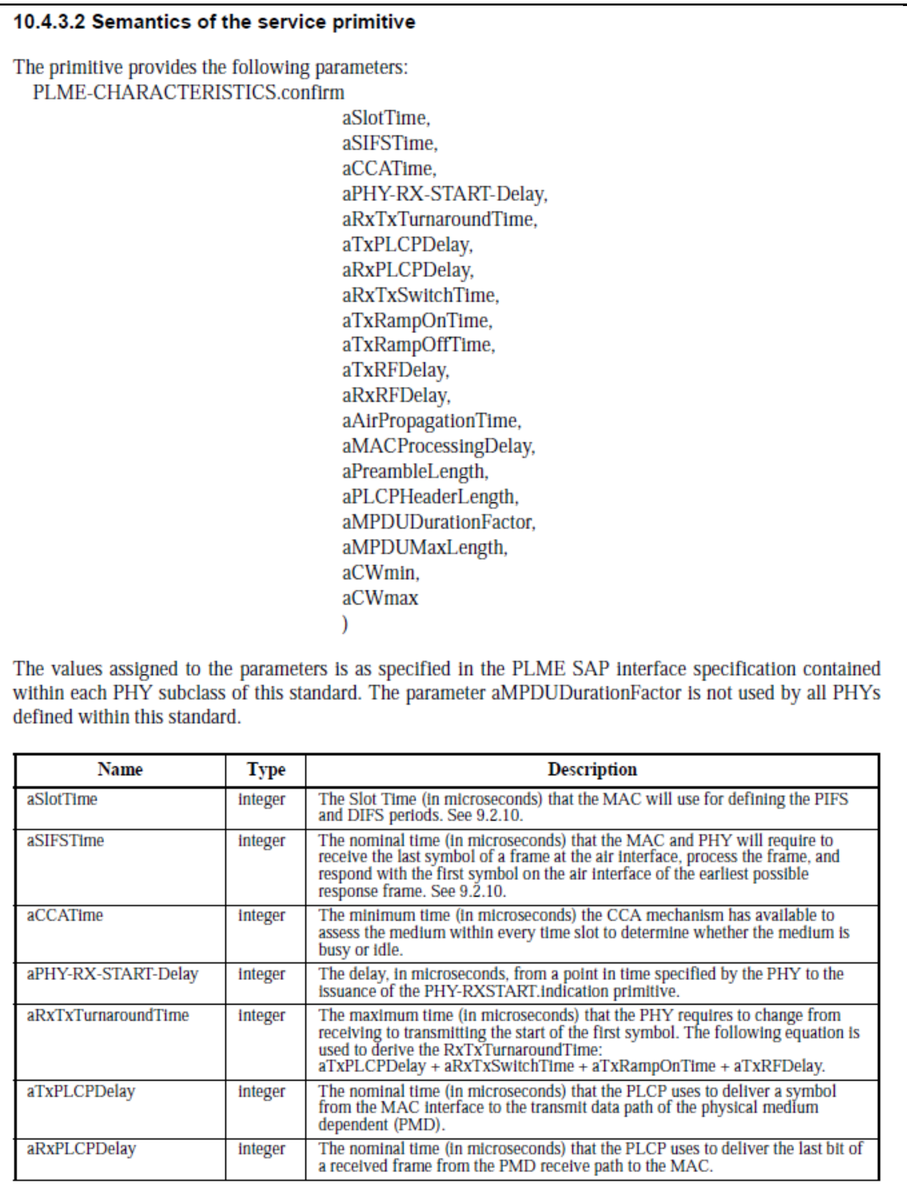
Claim 1 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 2 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
[2.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[2.2] wherein frequency difference between the first center frequency and the second center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range.	802.11-2007 discloses “wherein frequency difference between the first center frequency and the second center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium

Claim 2 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	5.2.3 Distribution system (DS) concepts PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

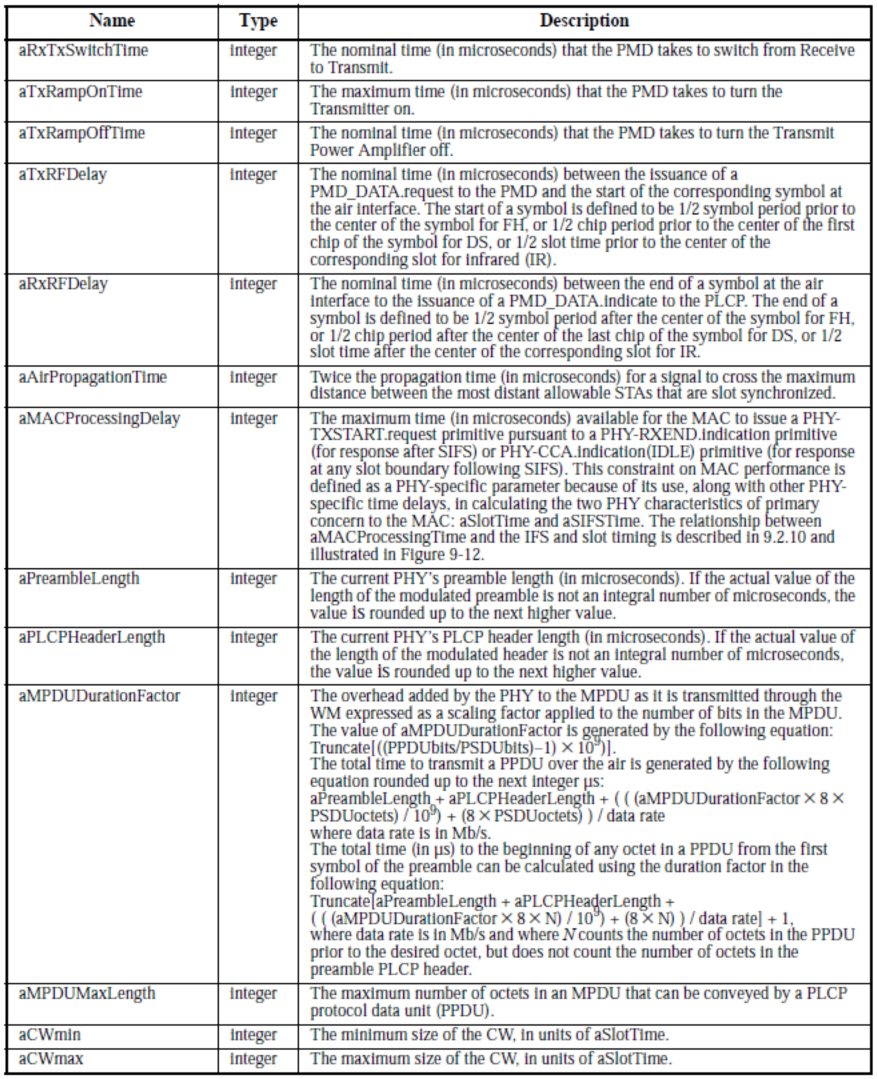
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 2 of the ’802 Patent	**Prior Art Reference – 802.11-2007**

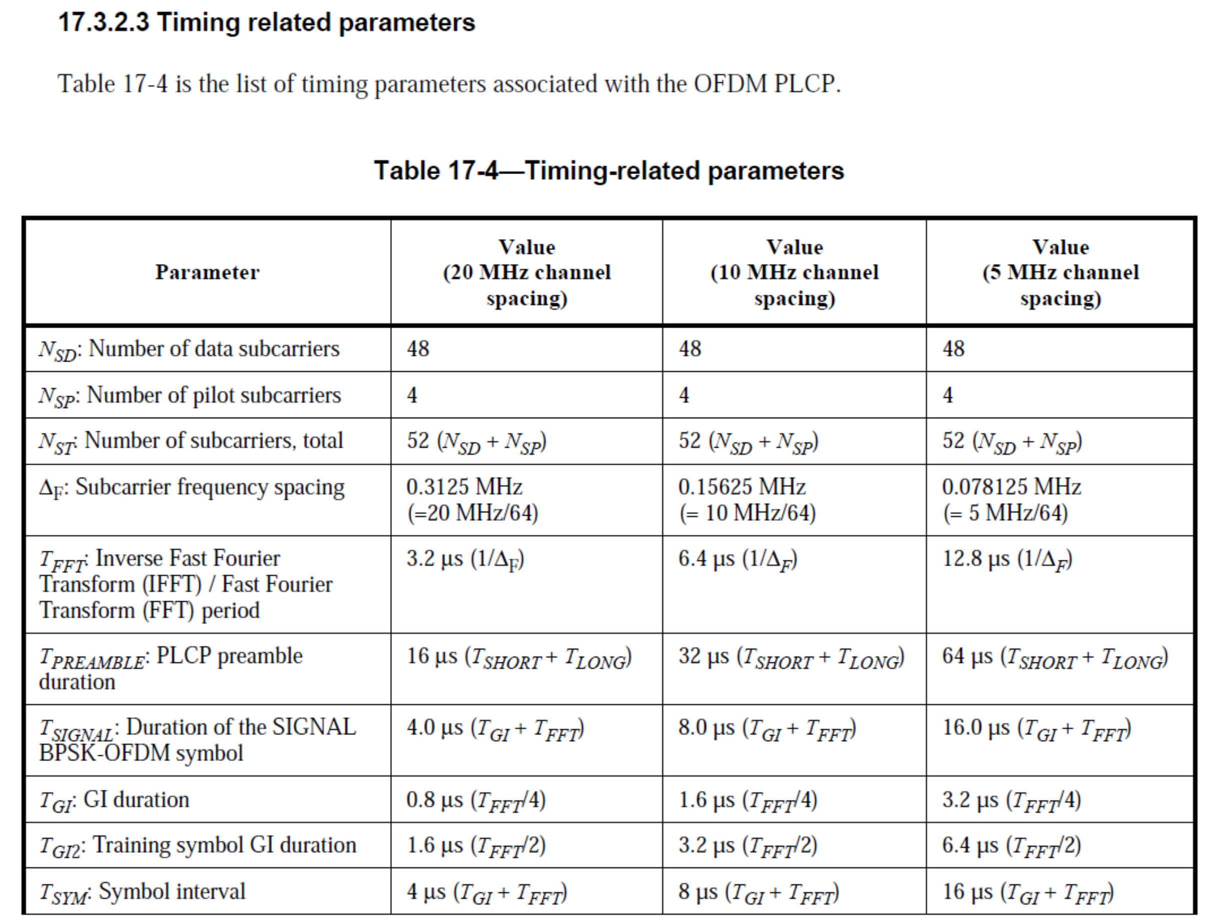


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

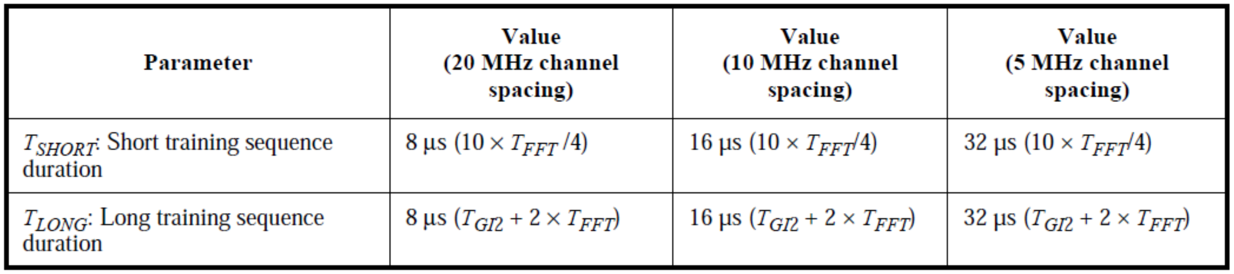
Claim 2 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

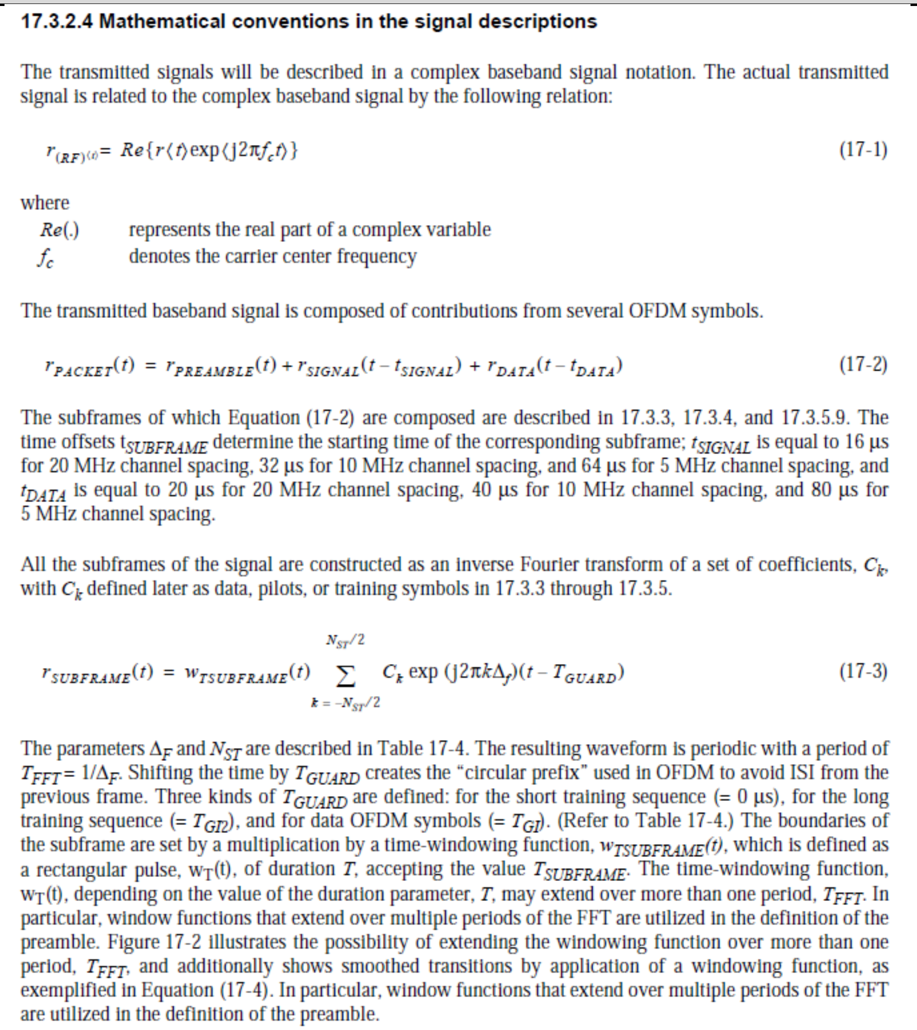
17.3.2.3 Timing related parameters

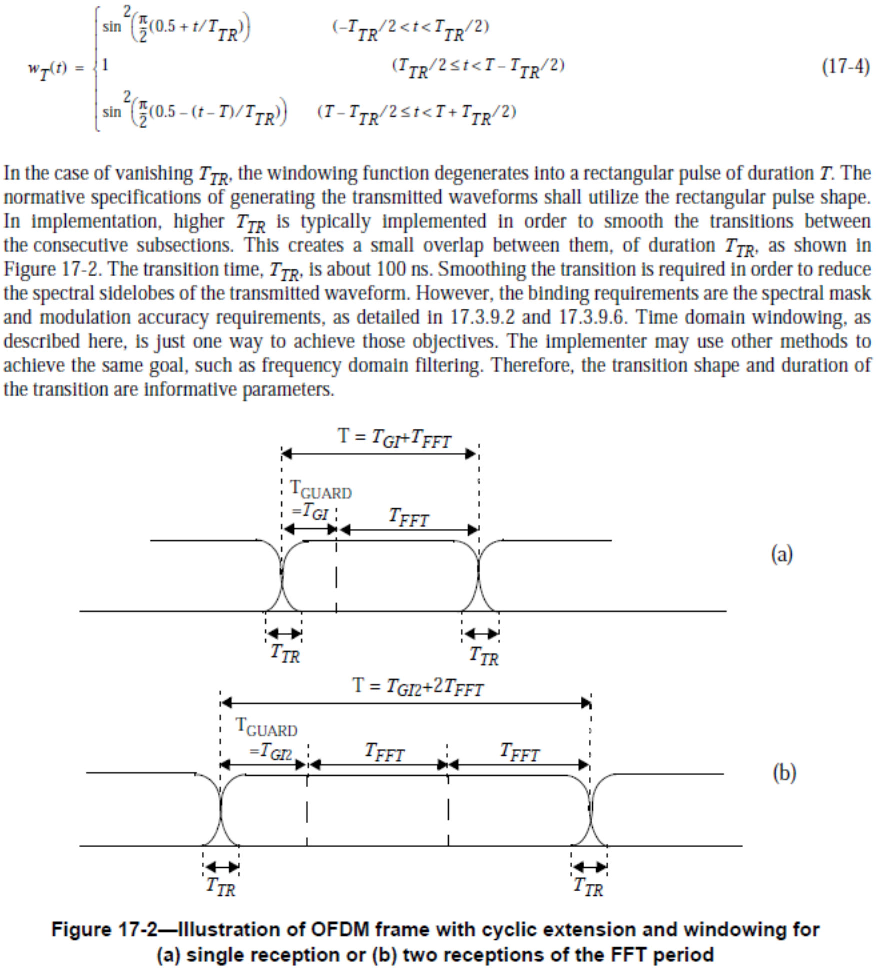
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

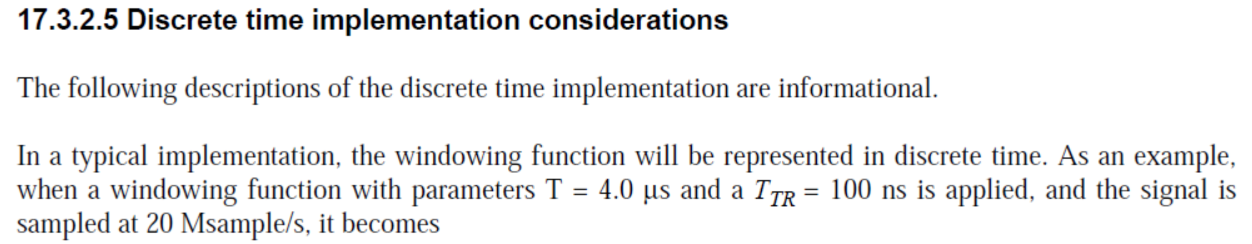
Table 17-4—Timing-related parameters

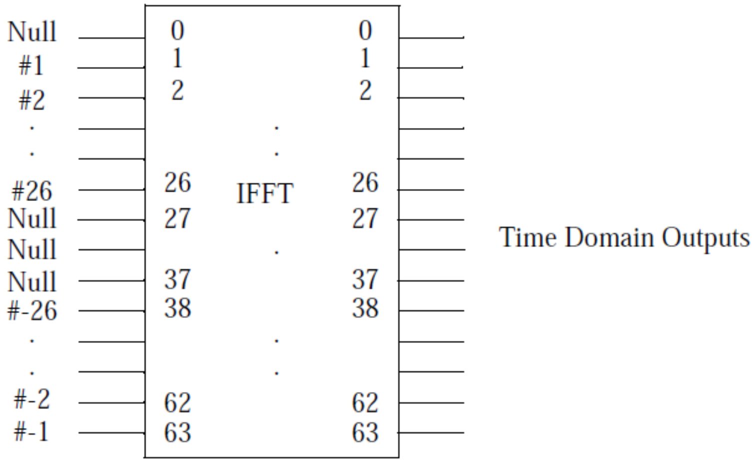
Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

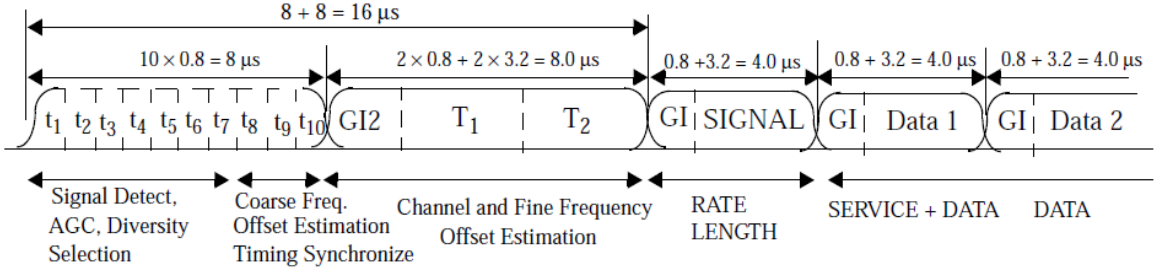
<table>
<tr><th>Claim 2 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

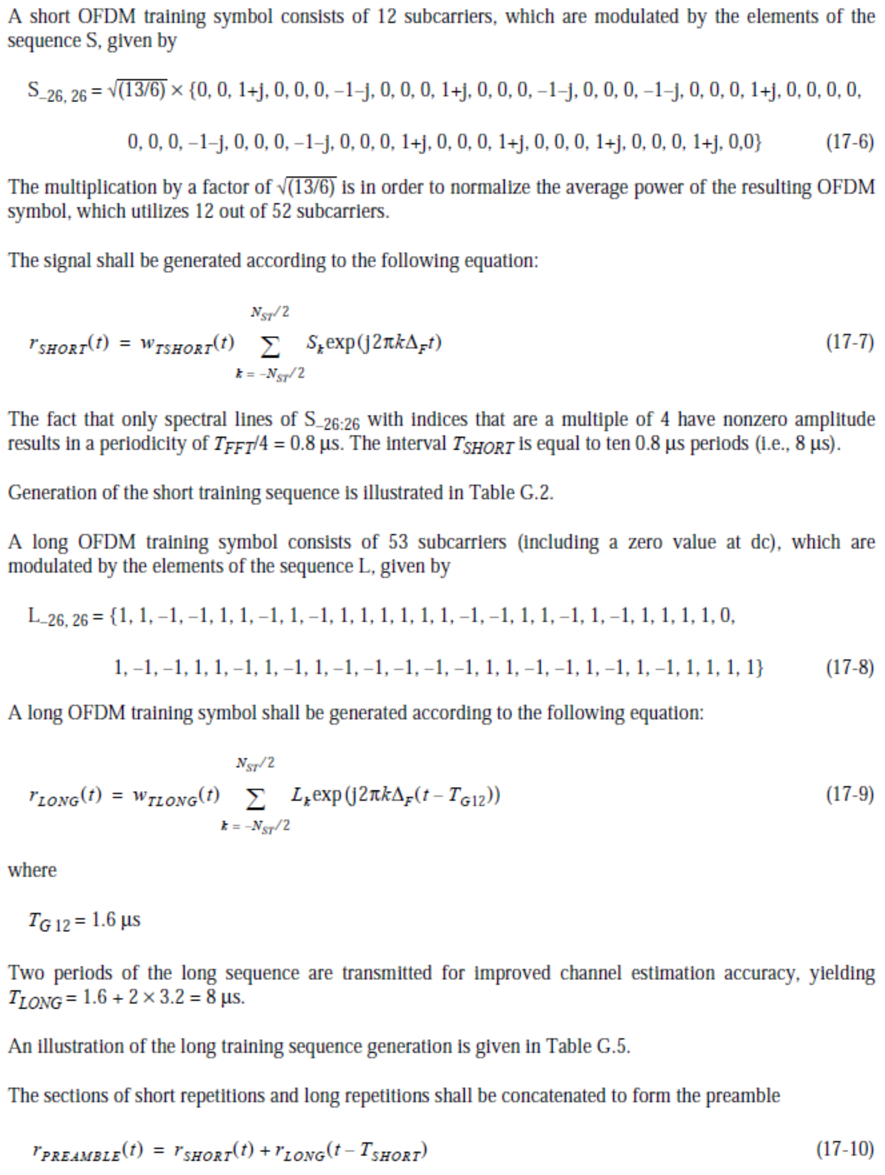
Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)(t)} = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 2 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 2 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & \text{otherwise} \end{cases}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ μs. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F(t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ μs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ μs.

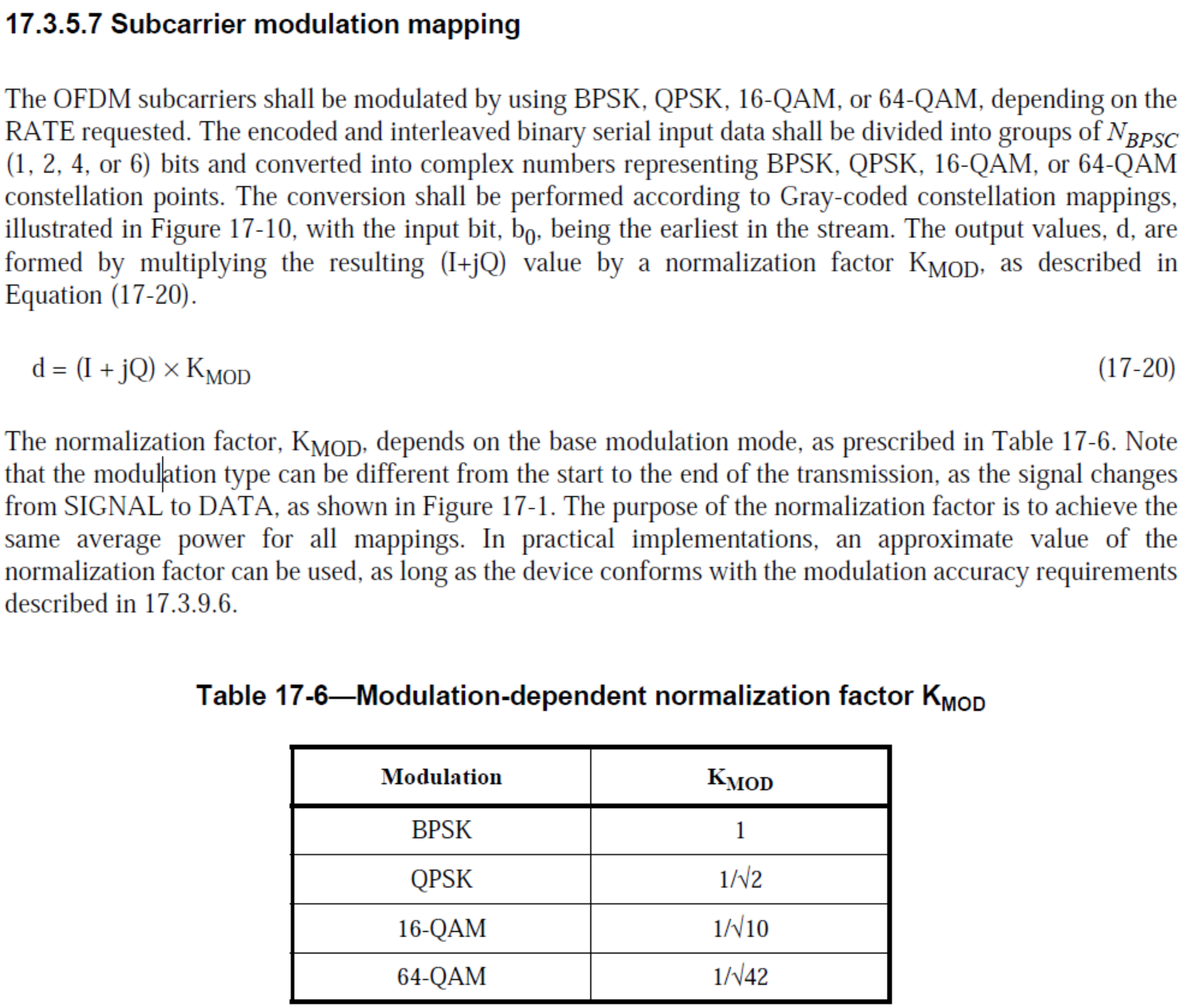
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 2 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD}-1,\ n = 0, \ldots N_{SYM}-1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$\begin{aligned} r_{DATA,n}(t) = w_{TSYM}(t)\Bigg(&\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) \\ &+ p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t-T_{GI}))\Bigg) \end{aligned} \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$
\begin{aligned}
p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\
&1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\
&-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\
&-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\}
\end{aligned}
\qquad (17\text{-}25)
$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

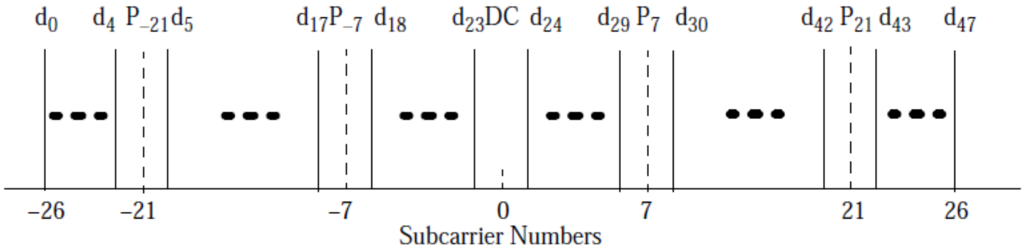


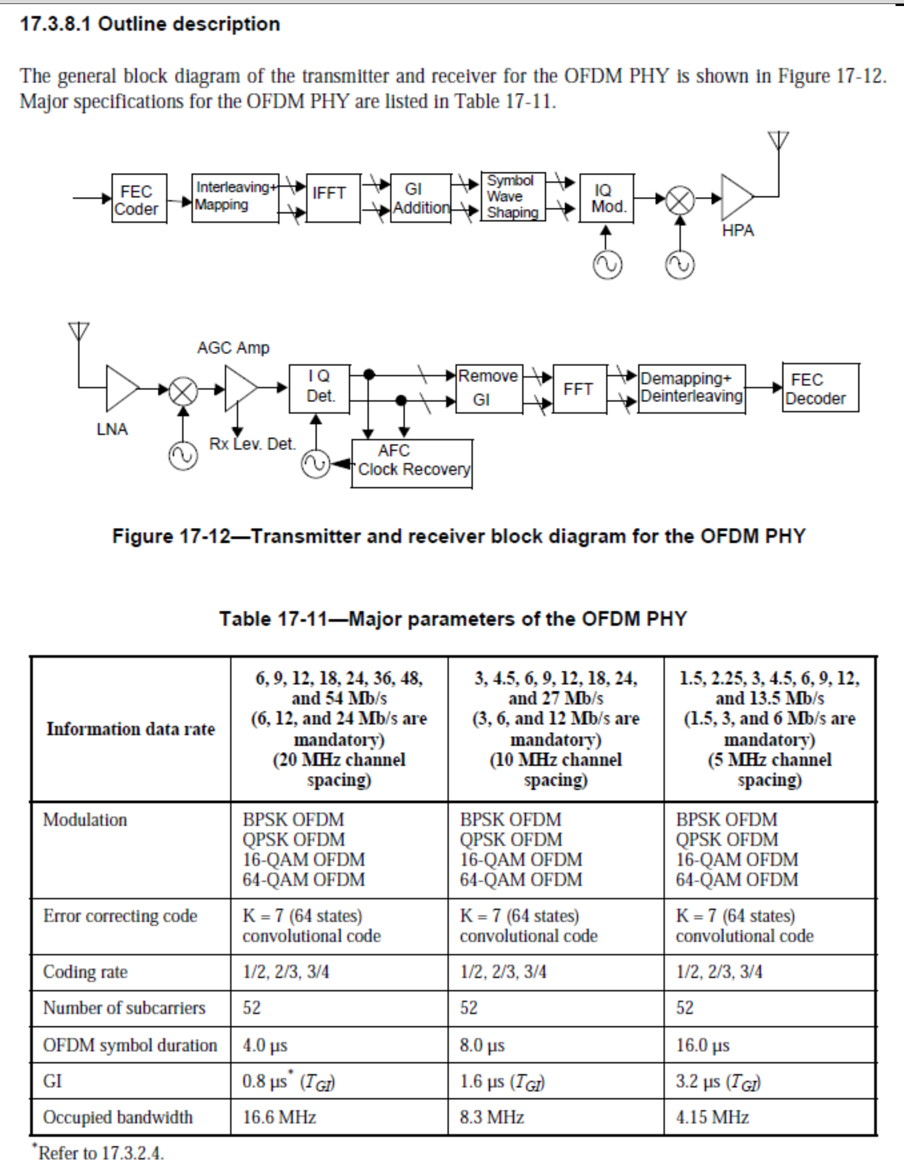
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$
r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)
$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 2 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

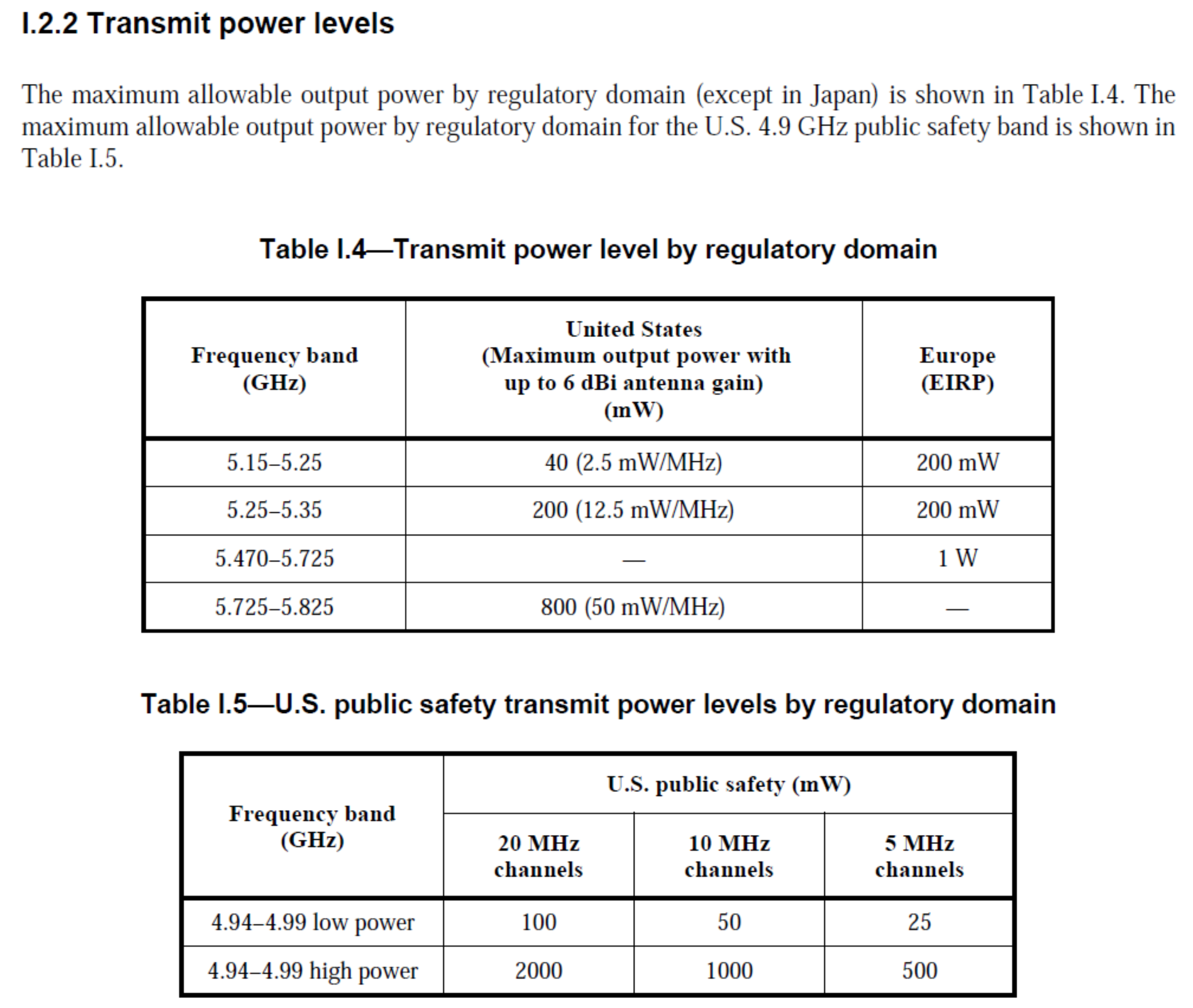
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

<table>
<tr><th>Claim 2 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


<h3>I.2.2 Transmit power levels</h3>

<p>The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.</p>

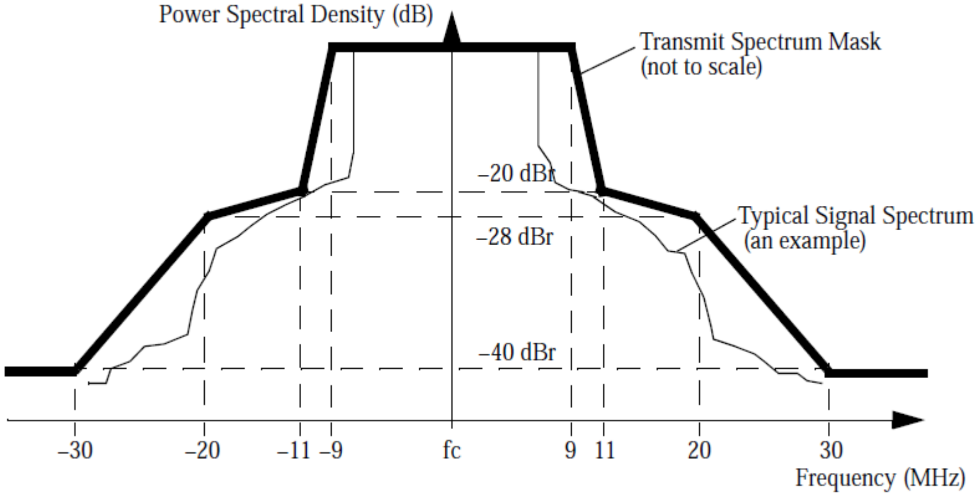
<p>Table I.4—Transmit power level by regulatory domain</p>

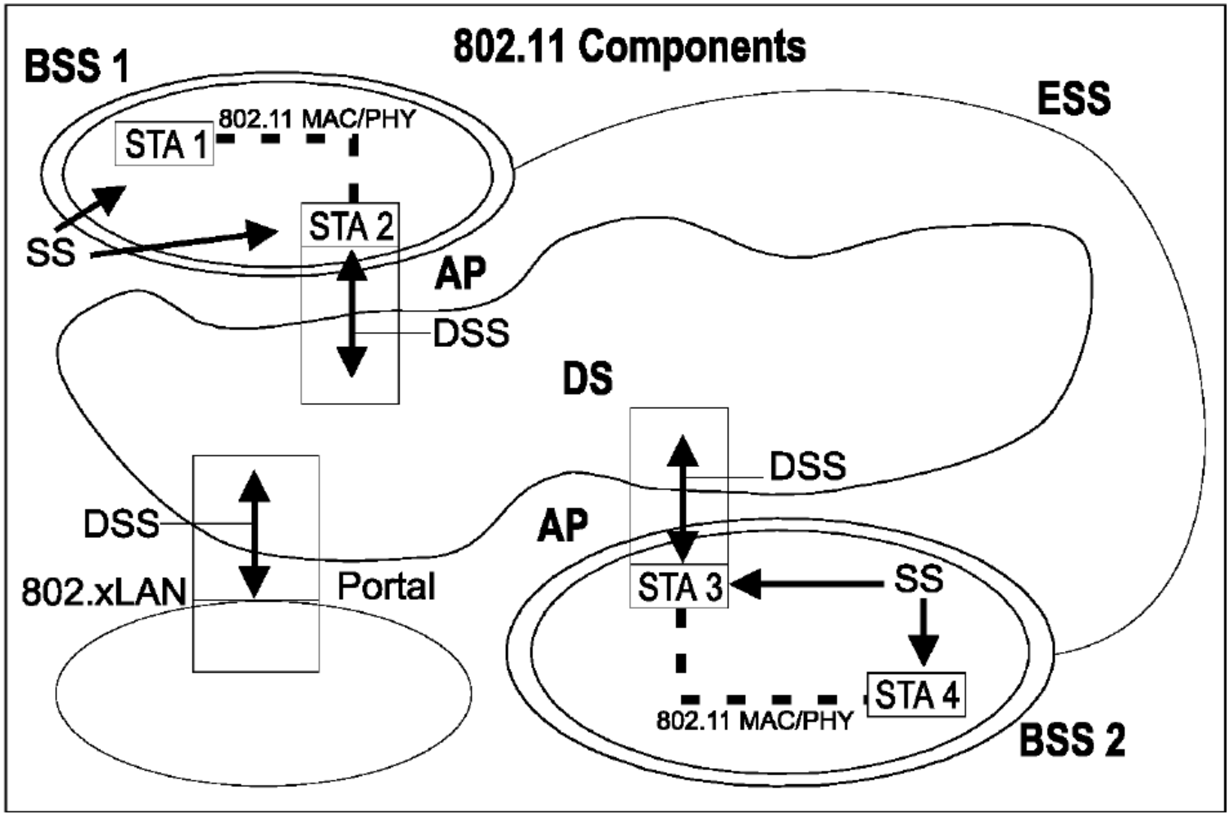
<table>
<tr><th>Frequency band (GHz)</th><th>United States (Maximum output power with up to 6 dBi antenna gain) (mW)</th><th>Europe (EIRP)</th></tr>
<tr><td>5.15–5.25</td><td>40 (2.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.25–5.35</td><td>200 (12.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.470–5.725</td><td>—</td><td>1 W</td></tr>
<tr><td>5.725–5.825</td><td>800 (50 mW/MHz)</td><td>—</td></tr>
</table>

<p>Table I.5—U.S. public safety transmit power levels by regulatory domain</p>

<table>
<tr><th rowspan="2">Frequency band (GHz)</th><th colspan="3">U.S. public safety (mW)</th></tr>
<tr><th>20 MHz channels</th><th>10 MHz channels</th><th>5 MHz channels</th></tr>
<tr><td>4.94–4.99 low power</td><td>100</td><td>50</td><td>25</td></tr>
<tr><td>4.94–4.99 high power</td><td>2000</td><td>1000</td><td>500</td></tr>
</table>

<p>See, e.g., 802.11-2007 § I.2.2</p>
</td></tr>
</table>

Claim 2 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

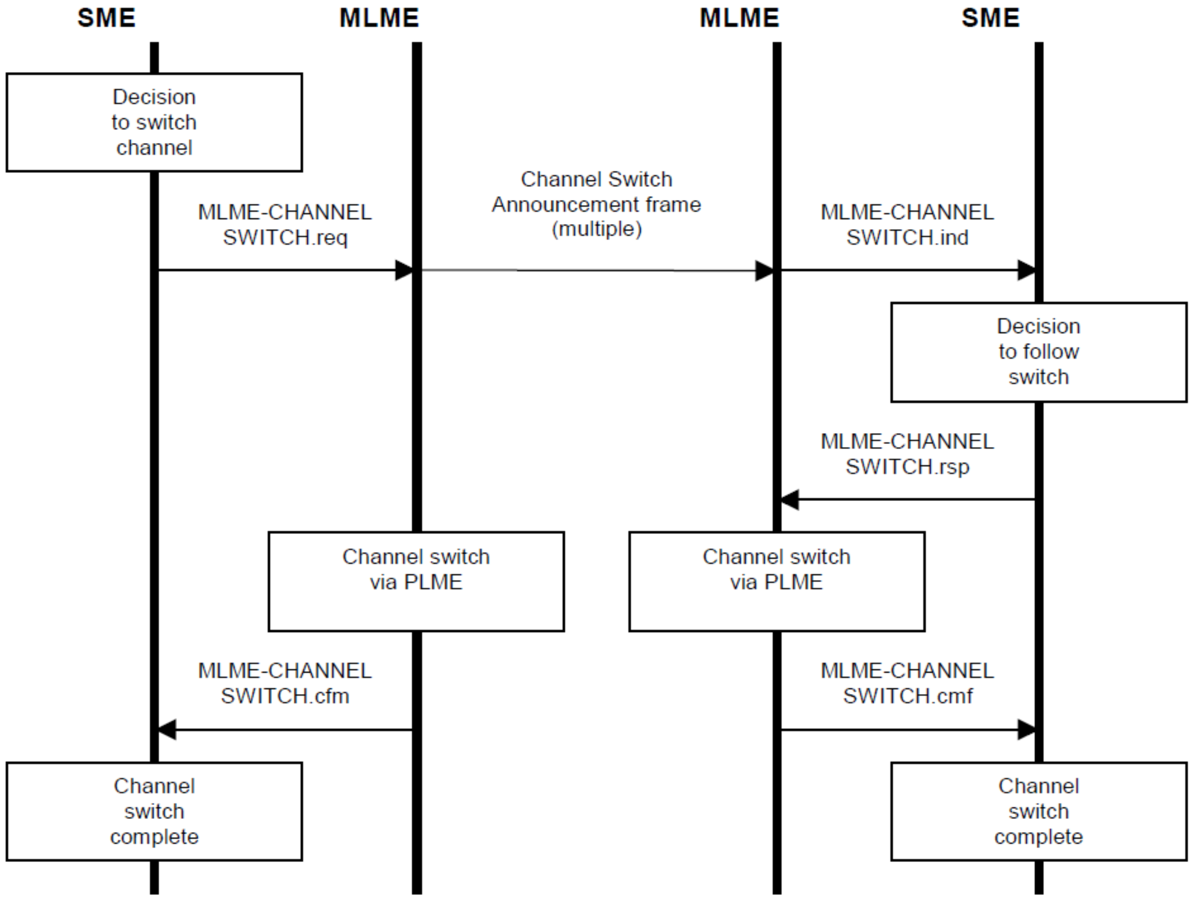
<table>
<tr><th>Claim 2 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

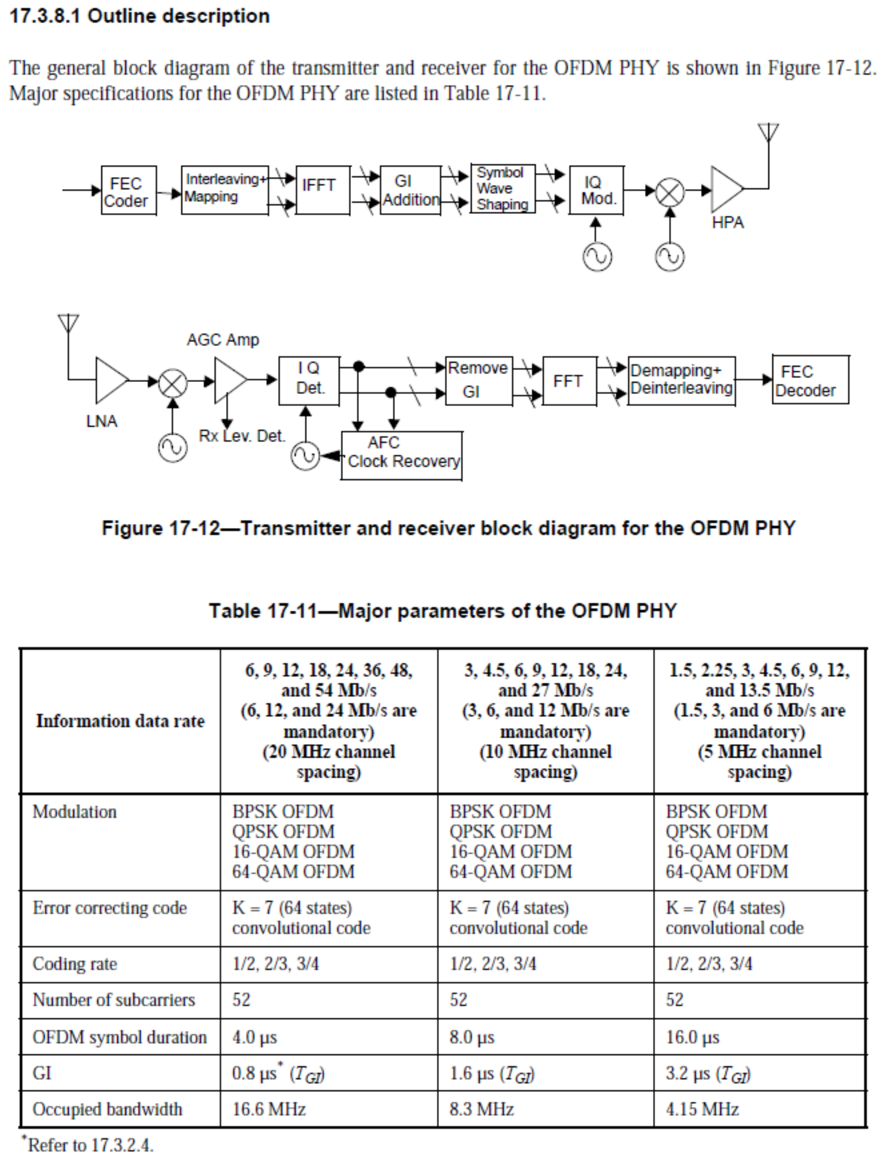
Figure 10-6—Channel switch

See, e.g., 802.11-2007 Figure 10-6

Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-</td></tr>
</table>

Claim 2 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 3 of the ’802 Patent	Prior Art Reference – 802.11-2007
[3.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[3.2] wherein the first and second information are transmitted using the same power amplifier in said wireless transmitter.	802.11-2007 discloses “wherein the first and second information are transmitted using the same power amplifier in said wireless transmitter.” See, e.g.:

Claim 3 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

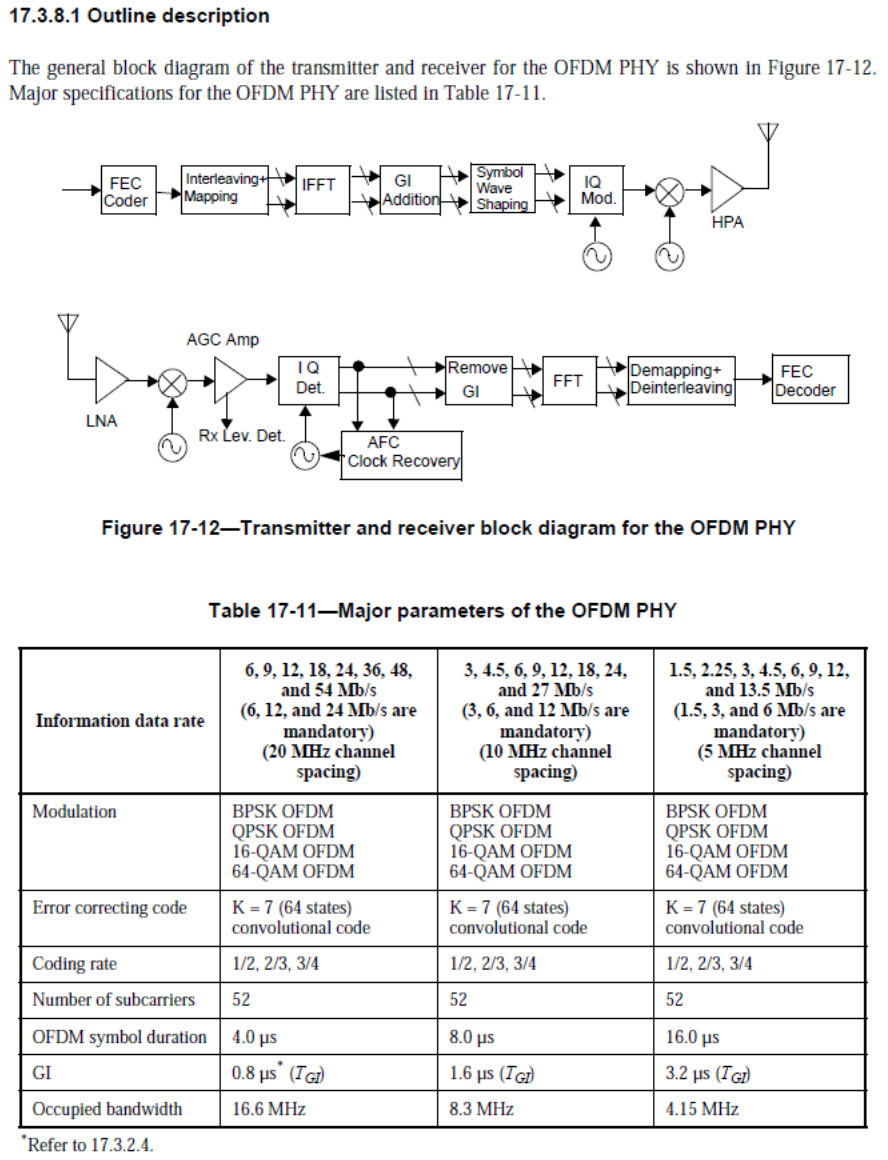
Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 3 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be

Claim 3 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 4 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
[4.1] The method of claim 3	802.11-2007 discloses all the elements of claim 3 for all the reasons provided above.
[4.2] wherein the bandwidth of said power amplifier is greater than the difference between the first lowest	802.11-2007 discloses “wherein the bandwidth of said power amplifier is greater than the difference between the first lowest frequency and the second highest frequency.” See, e.g.:

Claim 4 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
frequency and the second highest frequency.	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 4 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be

Claim 4 of the ’802 Patent	Prior Art Reference – 802.11-2007
	associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 6 of the '802 Patent	**Prior Art Reference – 802.11-2007**
[6.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[6.2] wherein the first information corresponds to a first wireless protocol and the second information corresponds to a second wireless protocol.	802.11-2007 discloses "wherein the first information corresponds to a first wireless protocol and the second information corresponds to a second wireless protocol." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
	possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
	Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by

Claim 6 of the ’802 Patent	Prior Art Reference – 802.11-2007
	regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

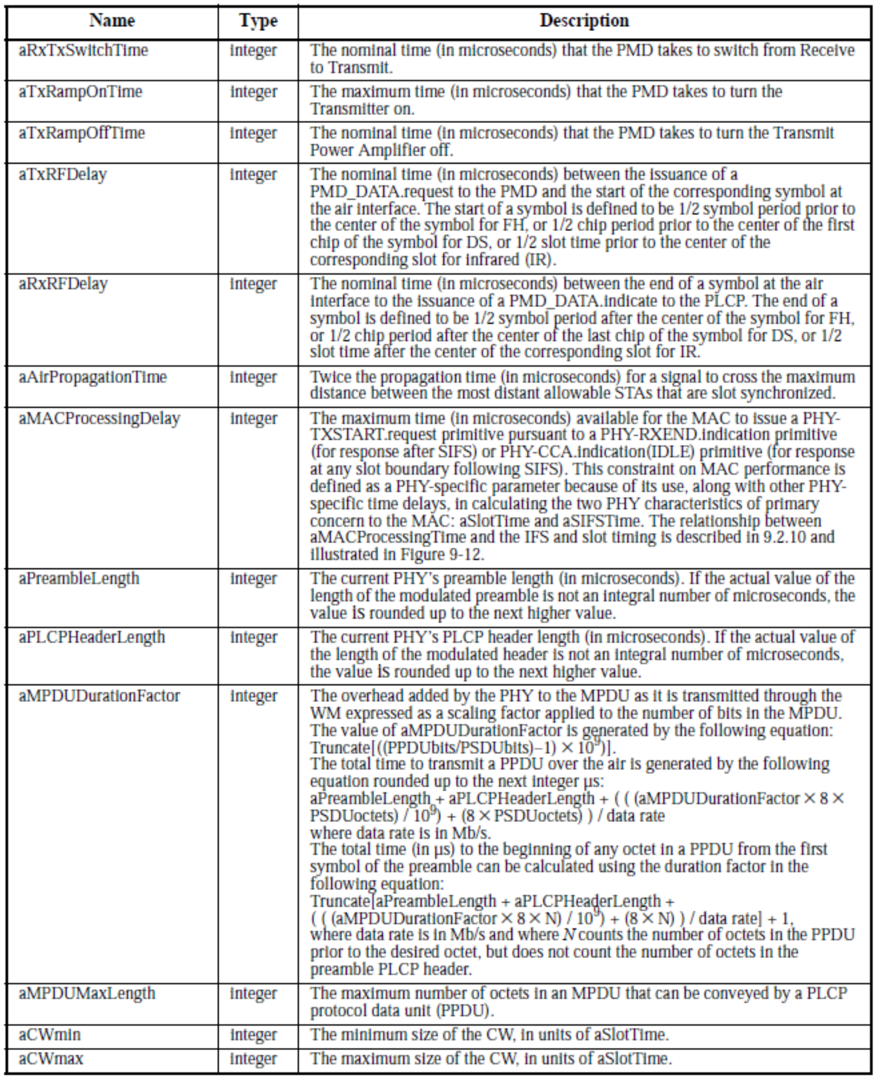
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 6 of the ’802 Patent	Prior Art Reference – 802.11-2007



Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 6 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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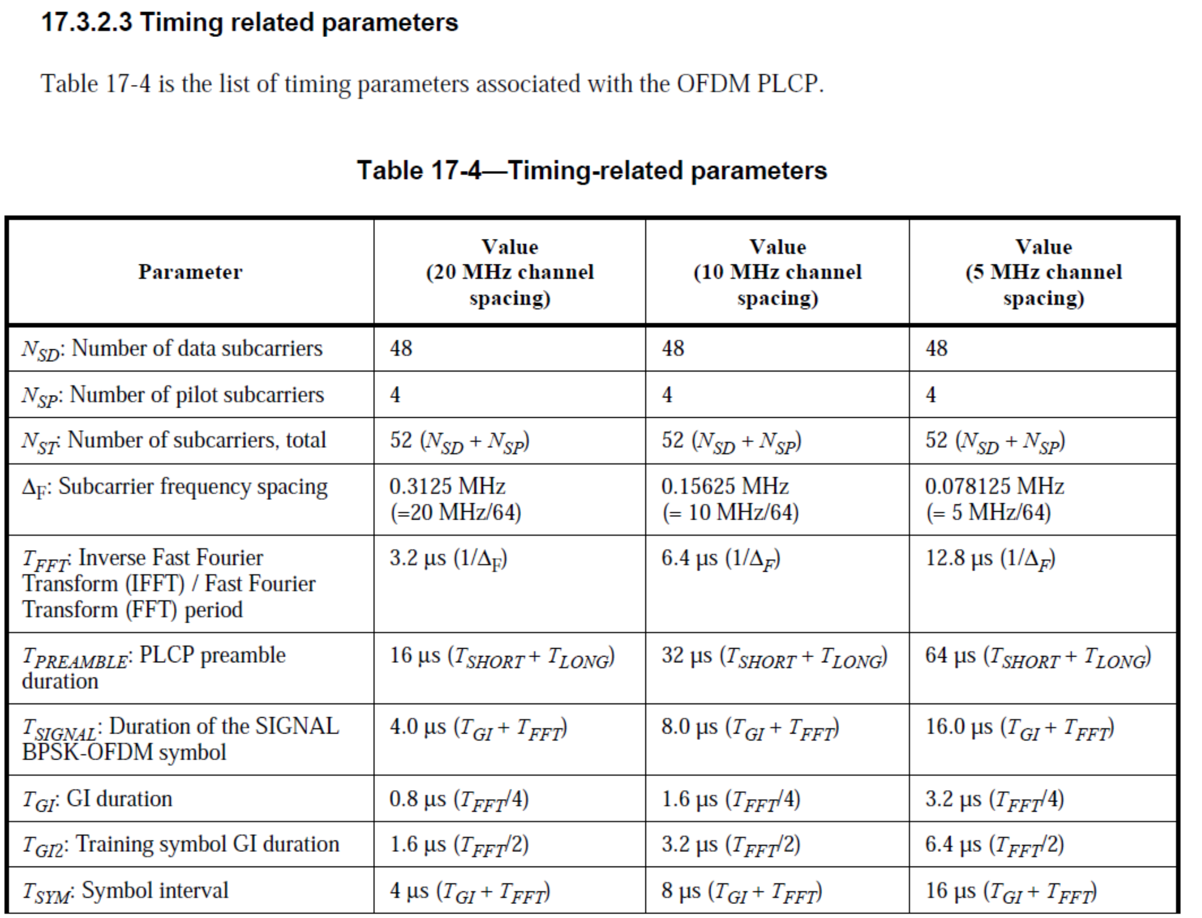
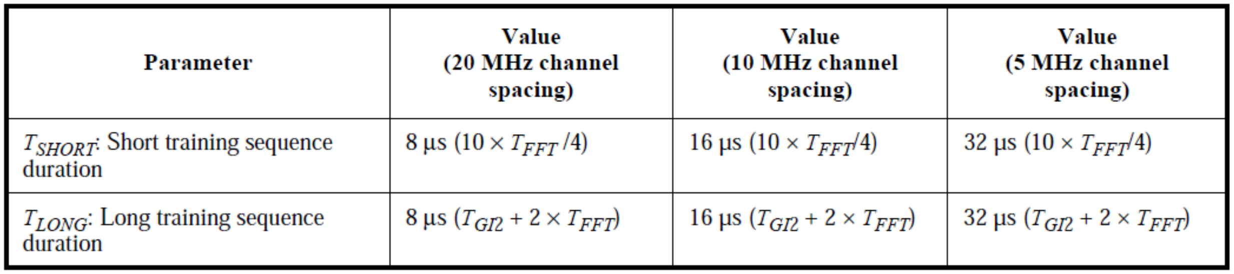


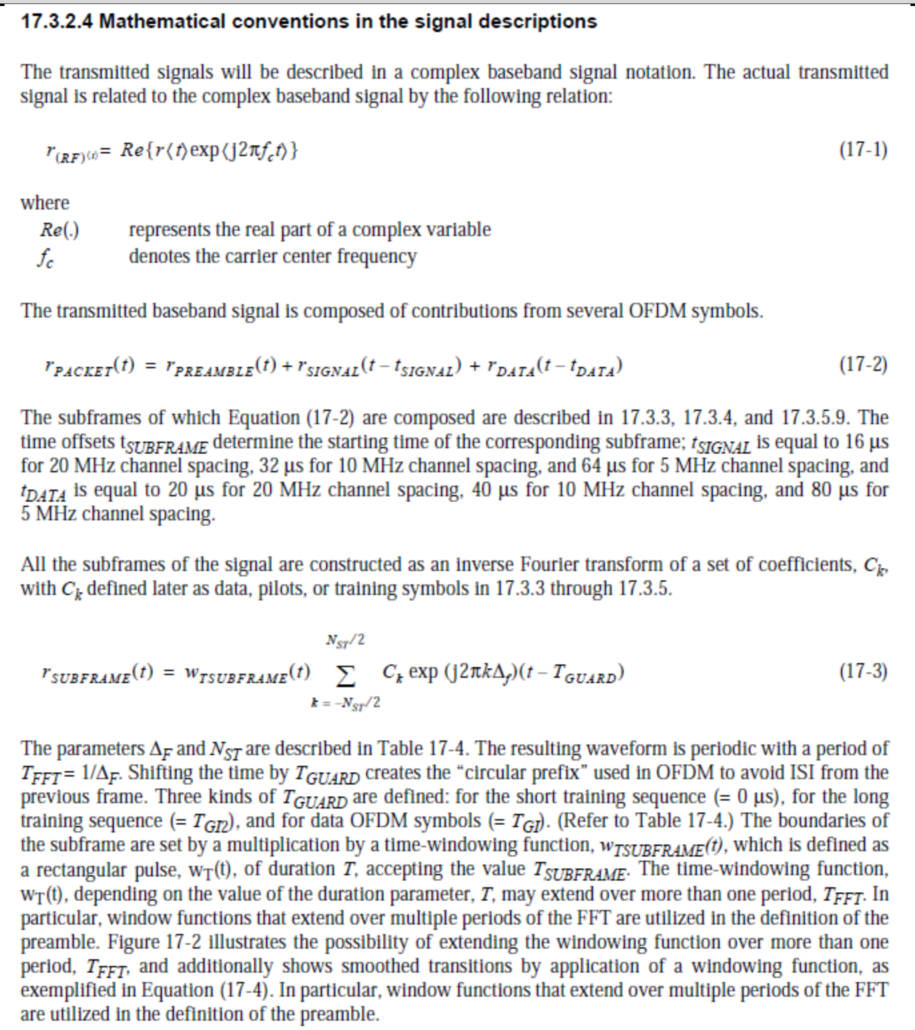
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 6 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 6 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)(t)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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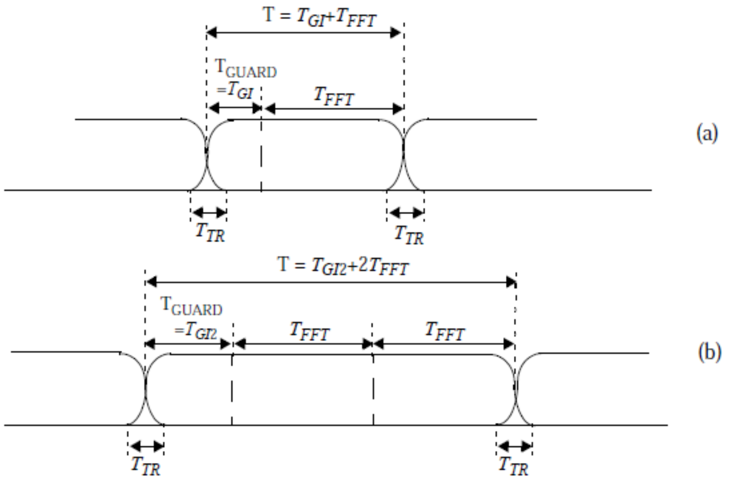
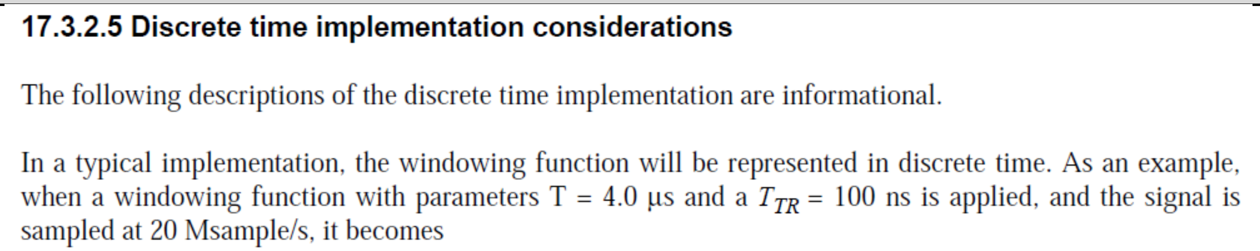
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 6 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 μs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

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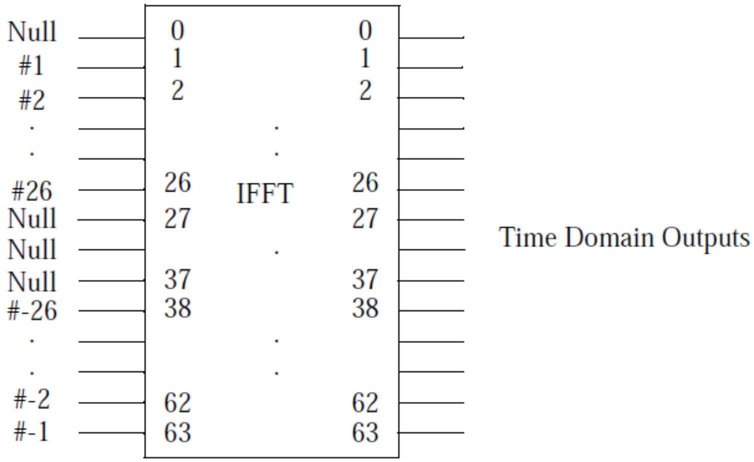
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

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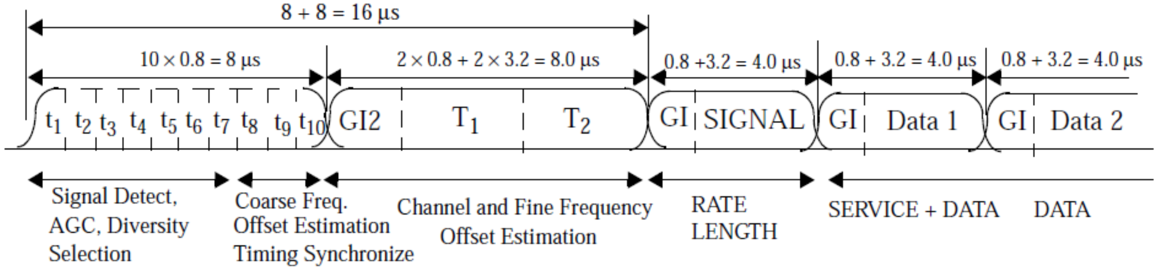
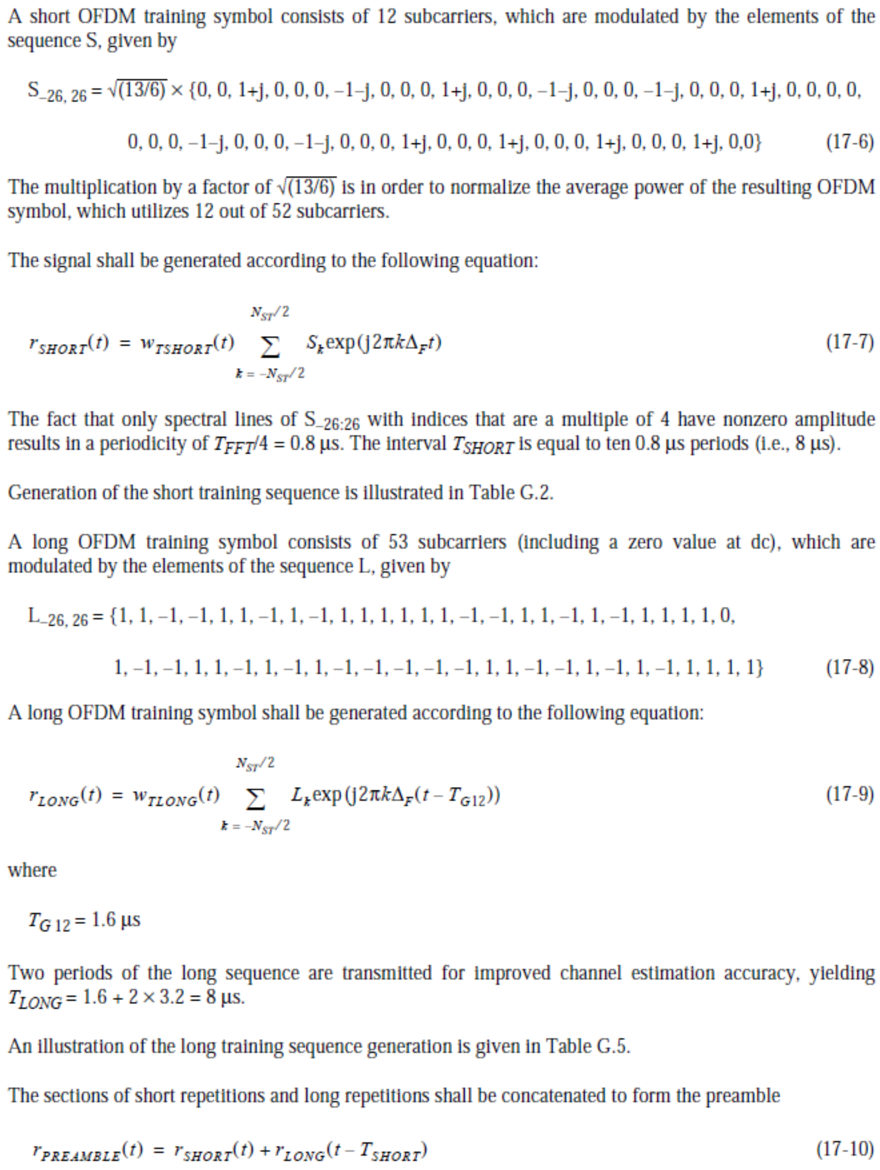
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

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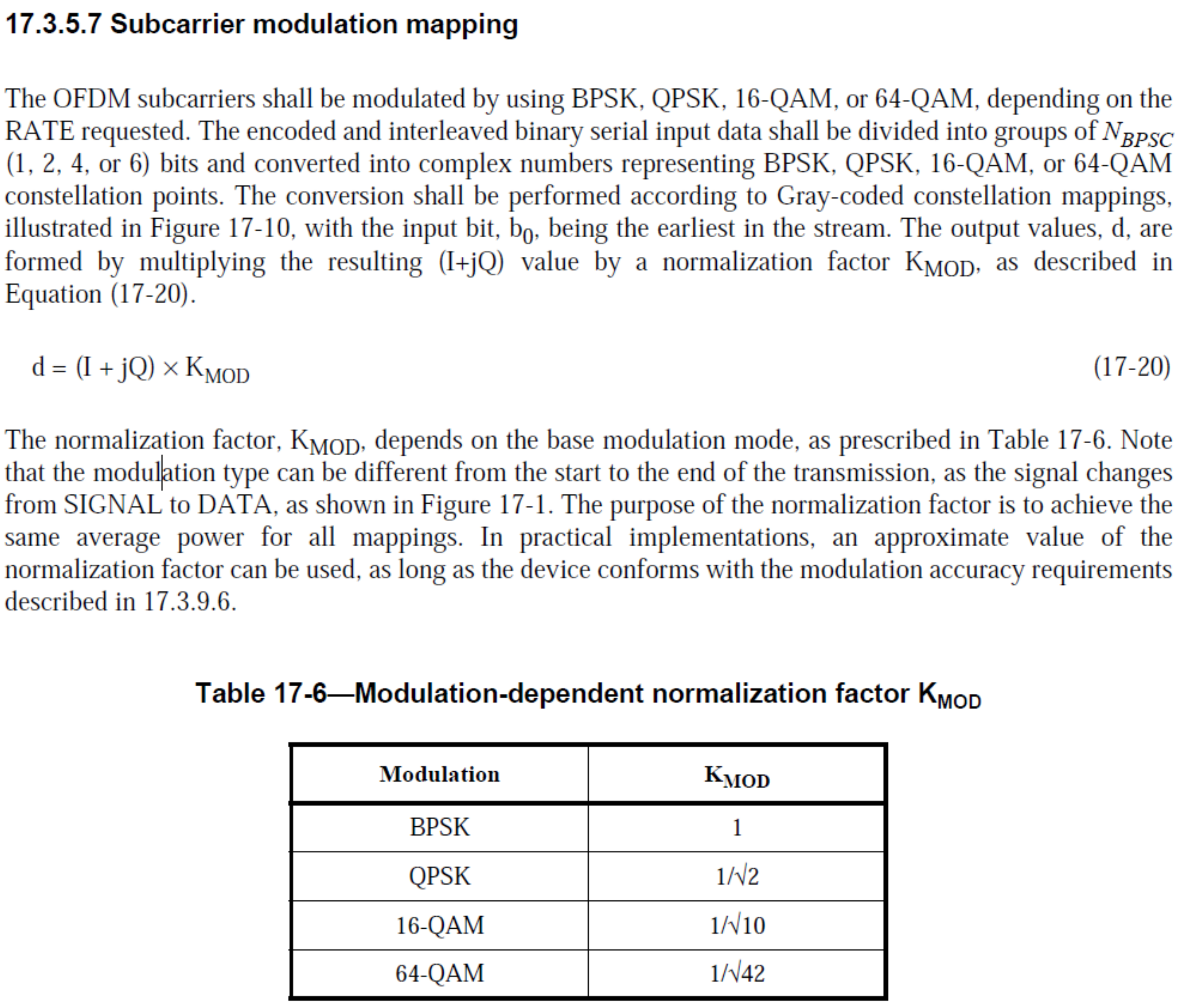

17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

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	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k + N_{SD} \times n}, \qquad k = 0, \ldots N_{SD} - 1, \ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$\begin{aligned} r_{DATA,n}(t) = w_{TSYM}(t) \Bigg(& \sum_{k=0}^{N_{SD}-1} d_{k,n} \exp((j2\pi M(k) \Delta_F (t - T_{GI})) \\ & + p_{n+1} \sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \Bigg) \end{aligned} \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{ & 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

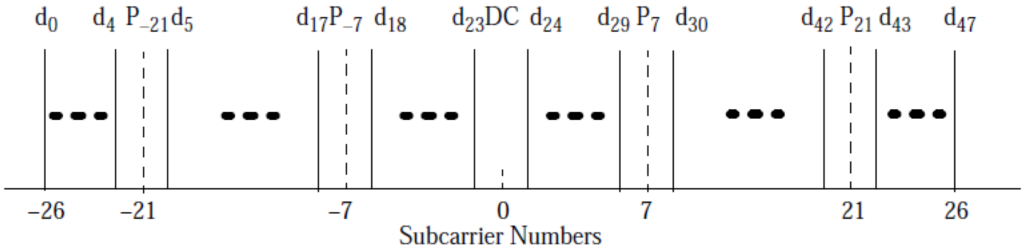

Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

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	See, e.g., 802.11-2007 § 17.3.5.9

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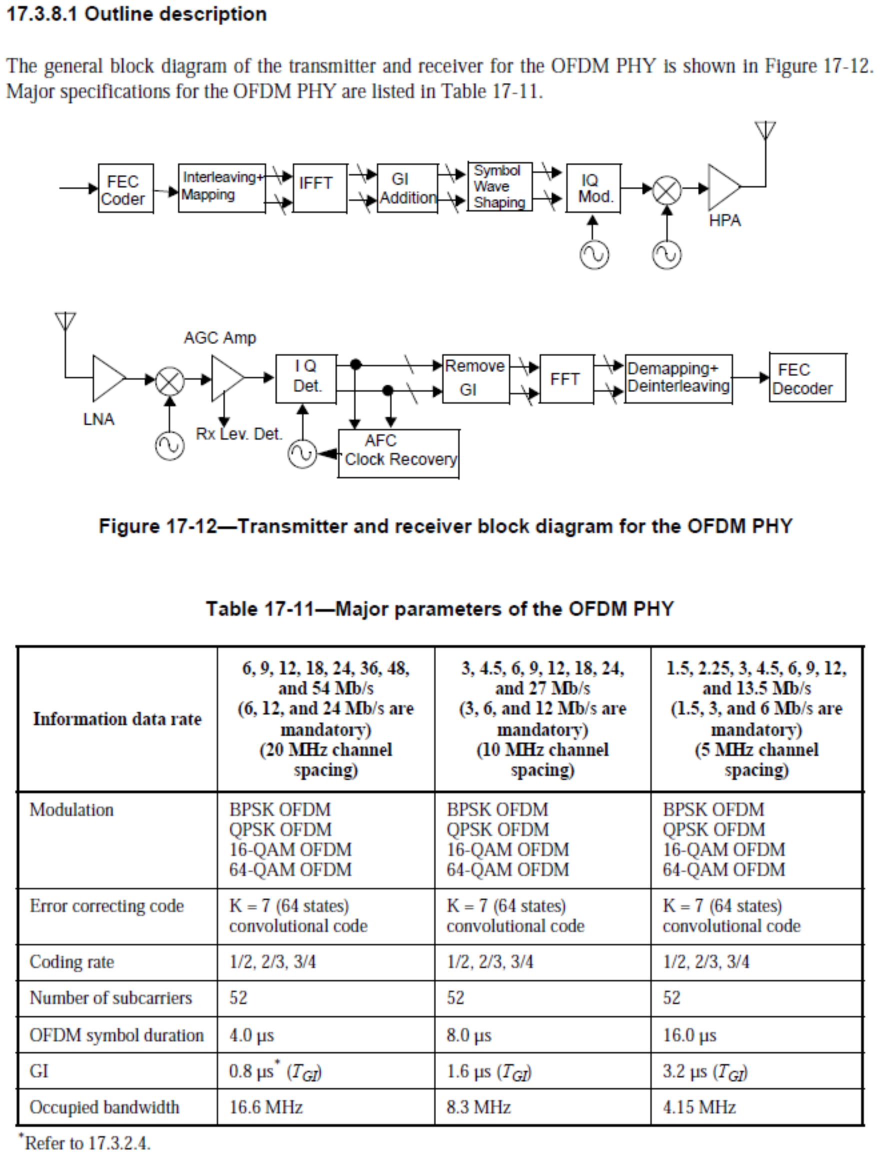


17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

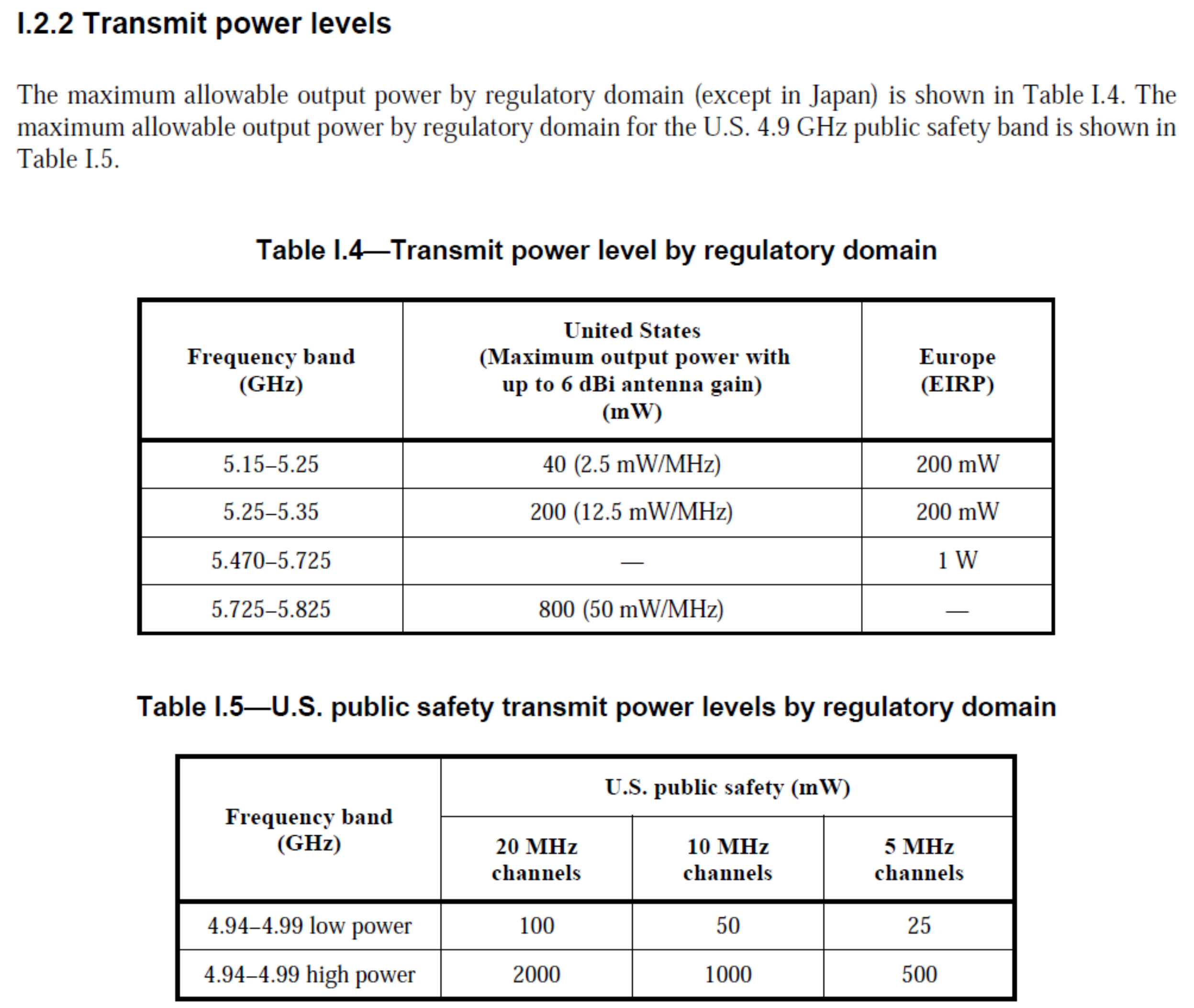
Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 6 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 6 of the ’802 Patent	**Prior Art Reference – 802.11-2007**



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

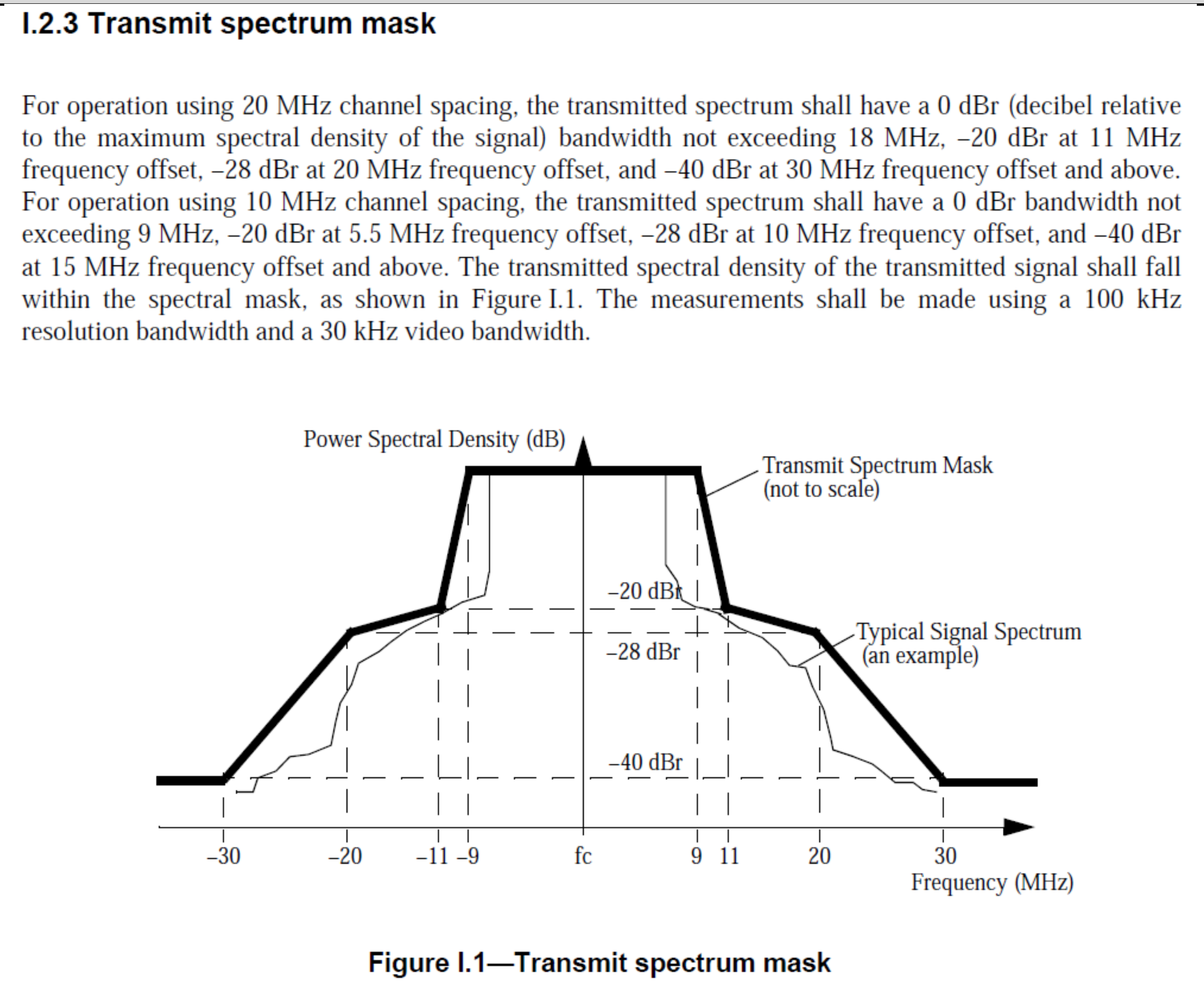
Table I.4—Transmit power level by regulatory domain

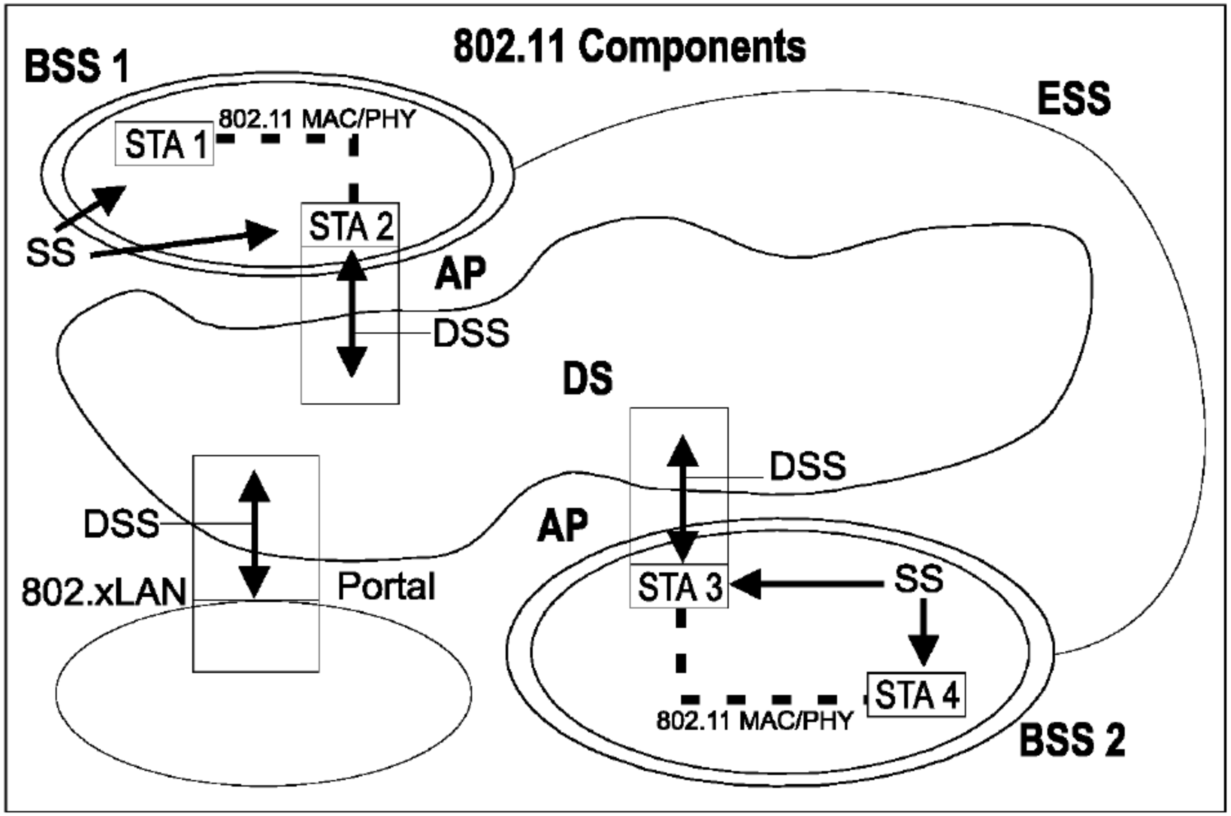
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

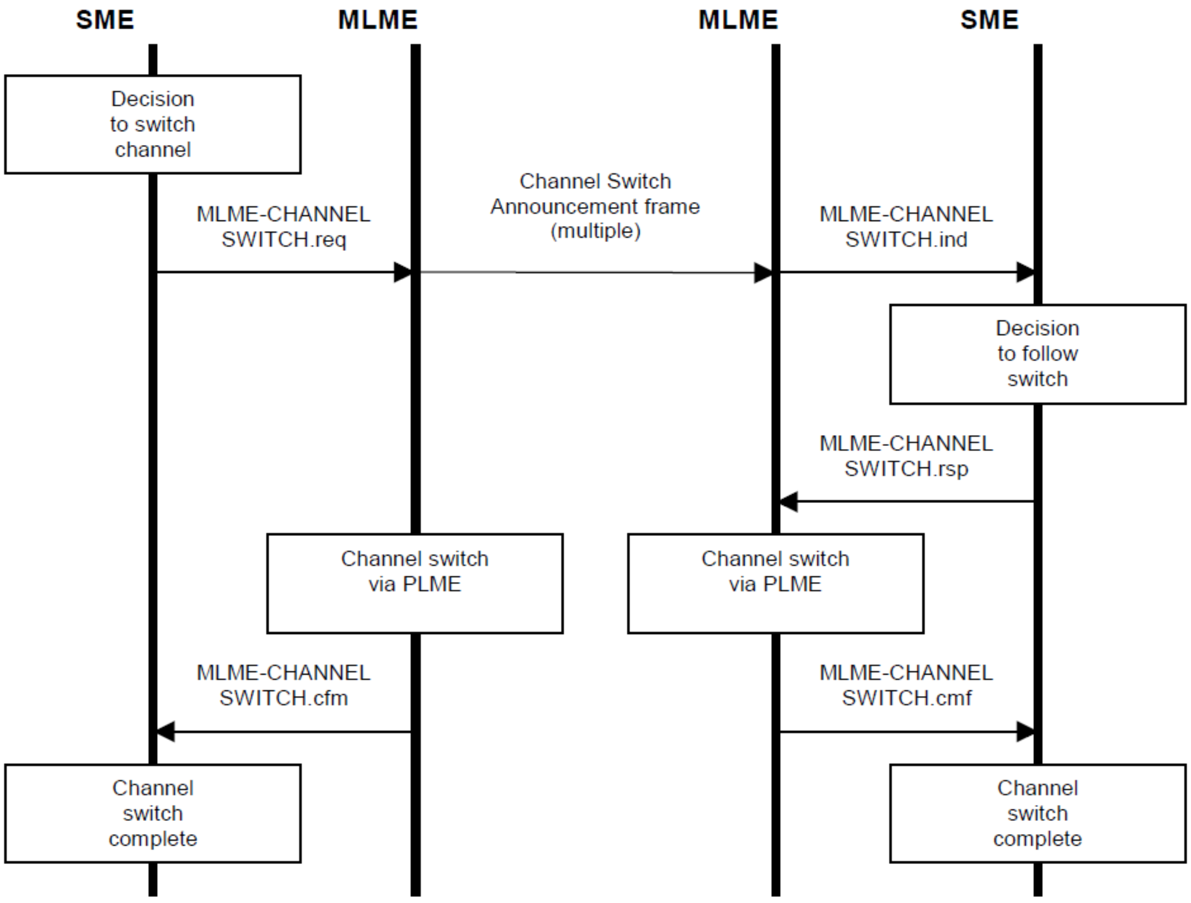
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 6 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 6 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 6 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 6 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 7 of the '802 Patent	**Prior Art Reference – 802.11-2007**
[7.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[7.2] wherein the first information and the second information are the same data transmitted across two different frequencies.	802.11-2007 discloses "wherein the first information and the second information are the same data transmitted across two different frequencies." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 7 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts**

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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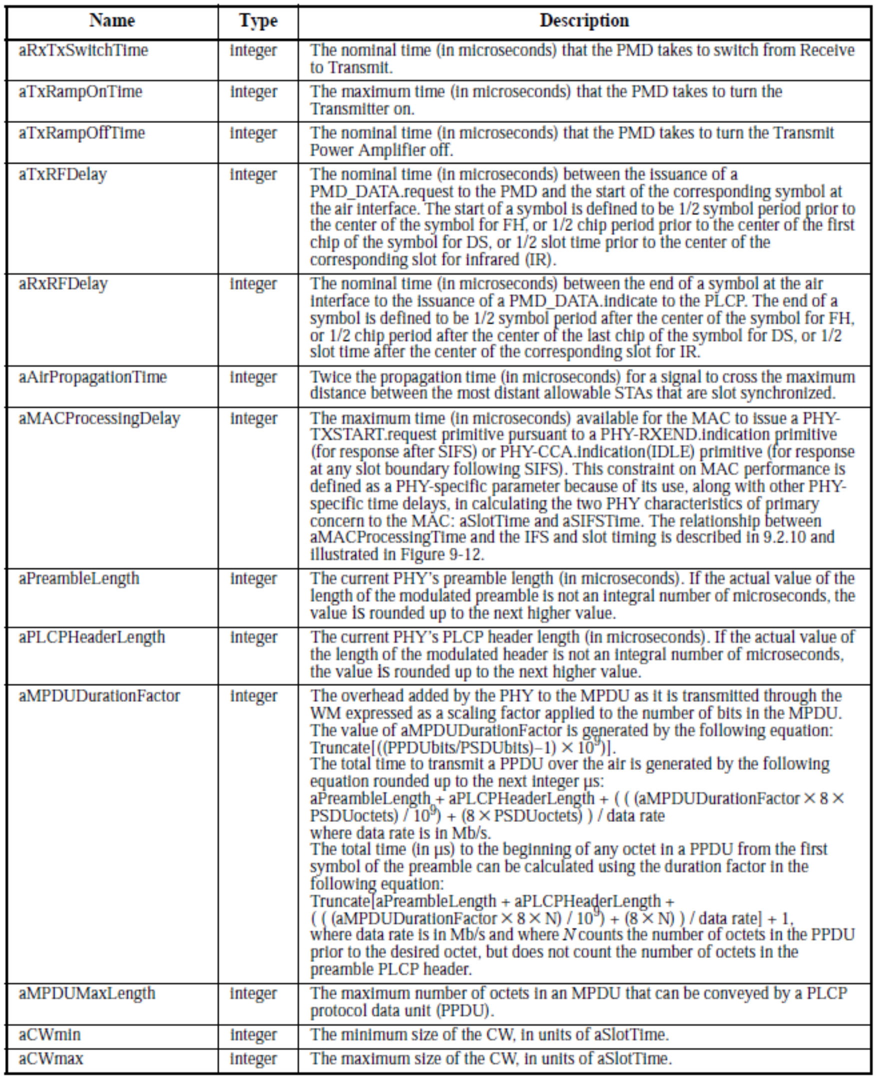
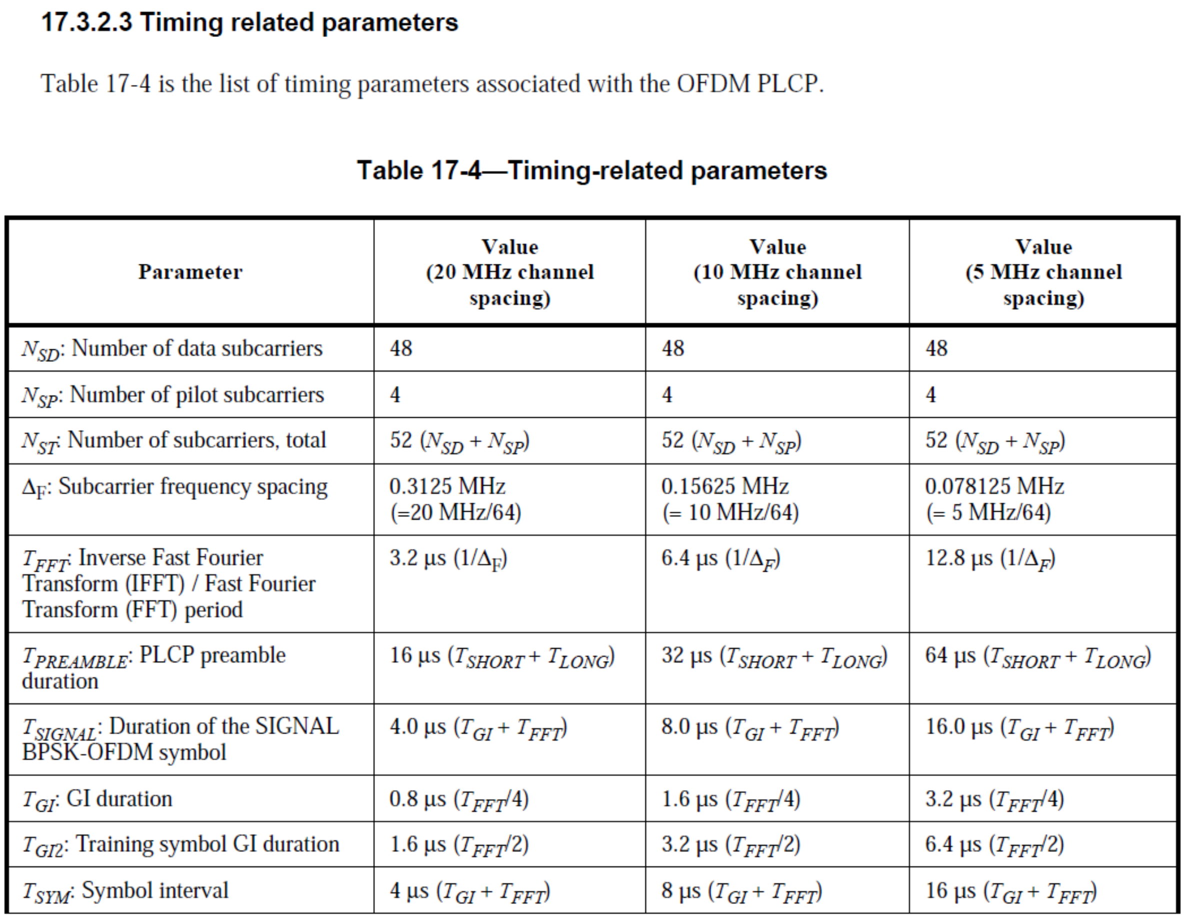


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 7 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 7 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

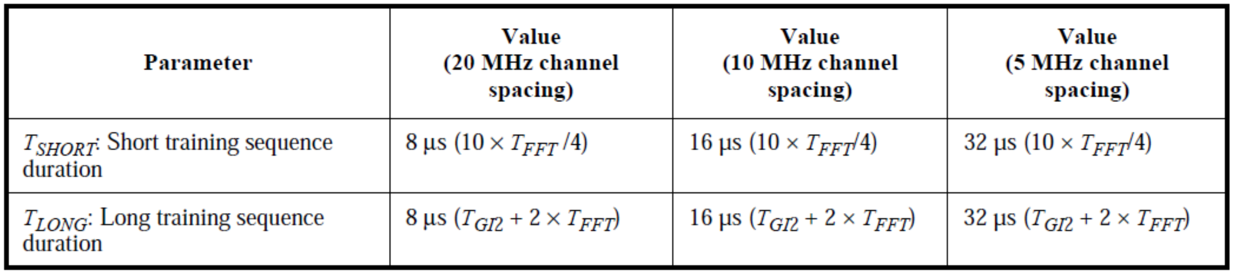
Claim 7 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

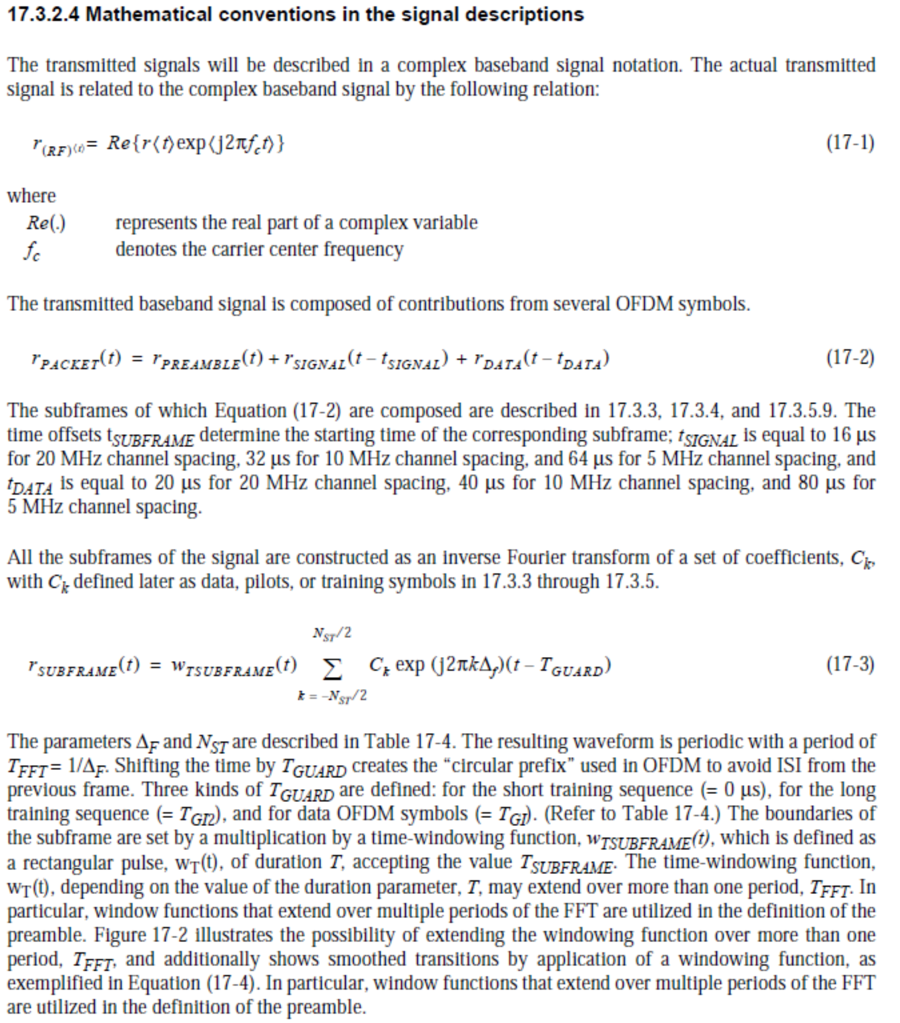
17.3.2.3 Timing related parameters

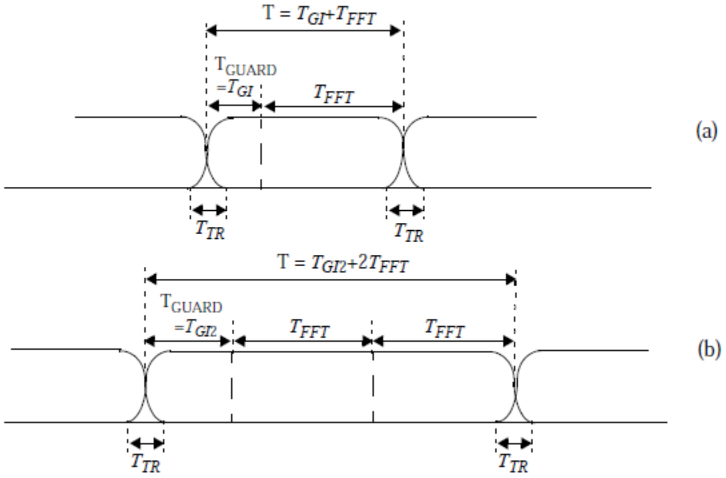
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

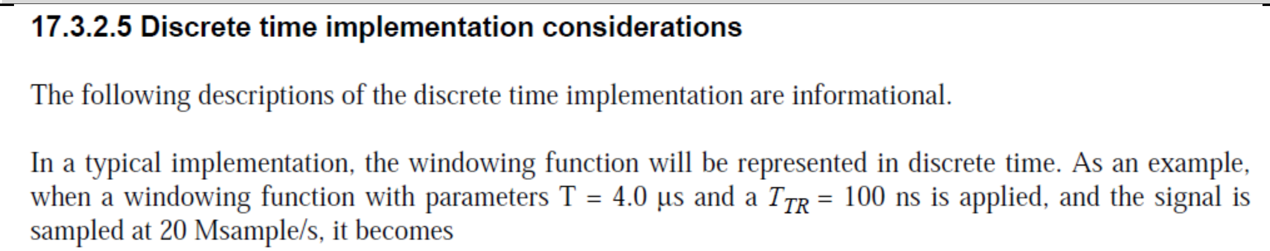
Table 17-4—Timing-related parameters

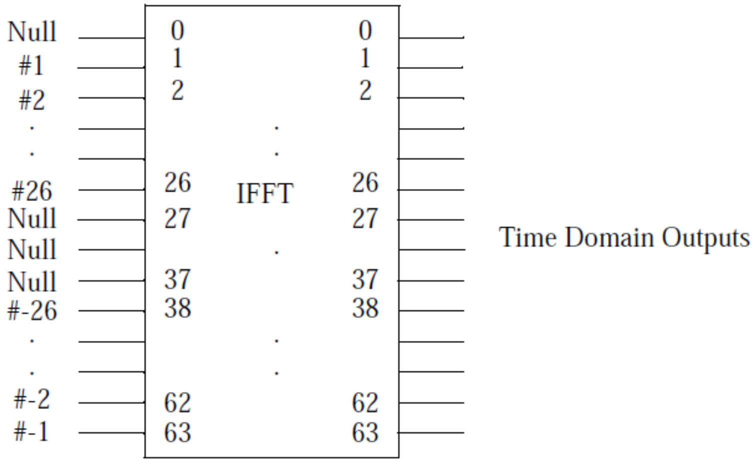
Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

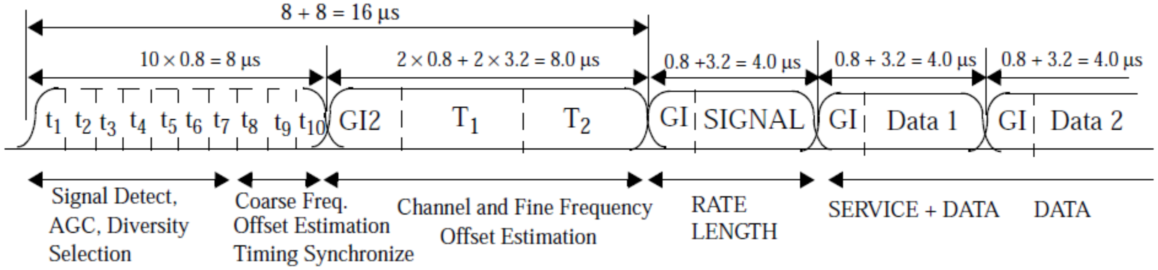
<table>
<tr><th>Claim 7 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

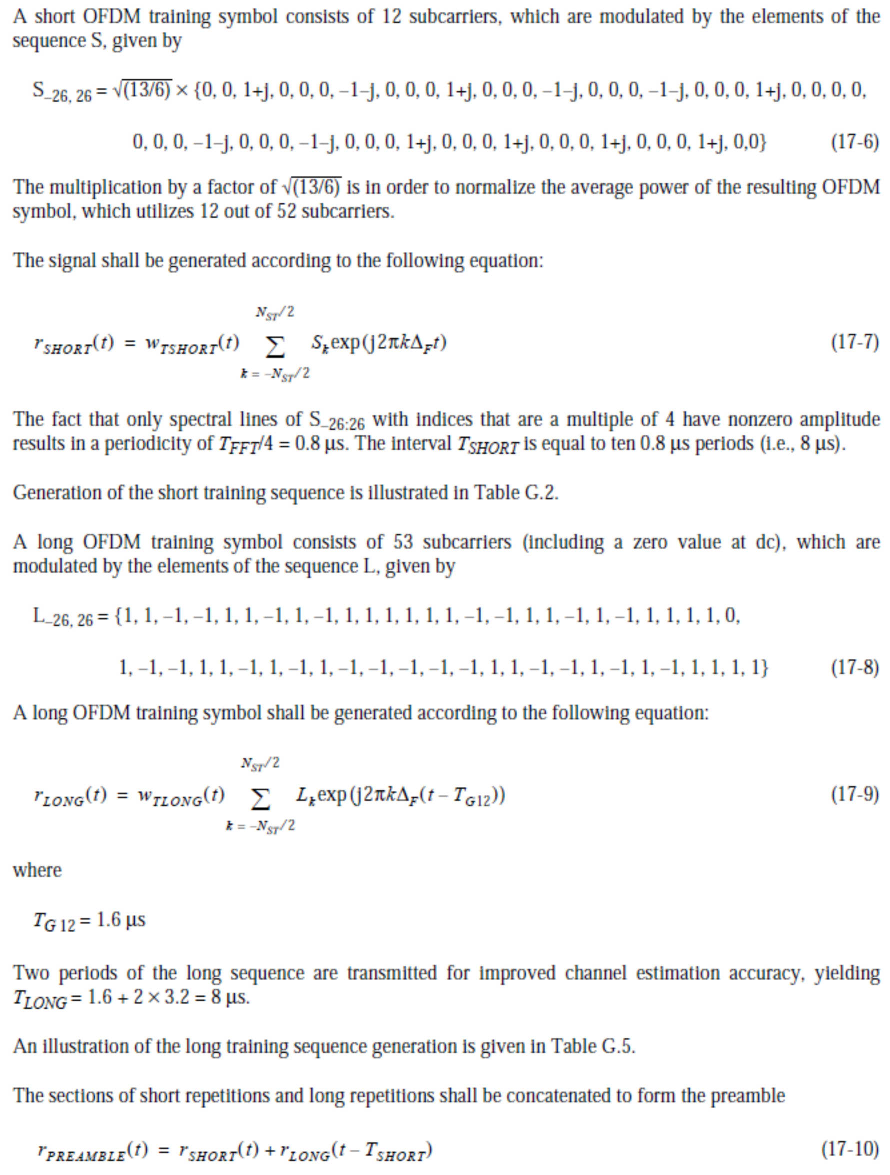
Claim 7 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 7 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 7 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

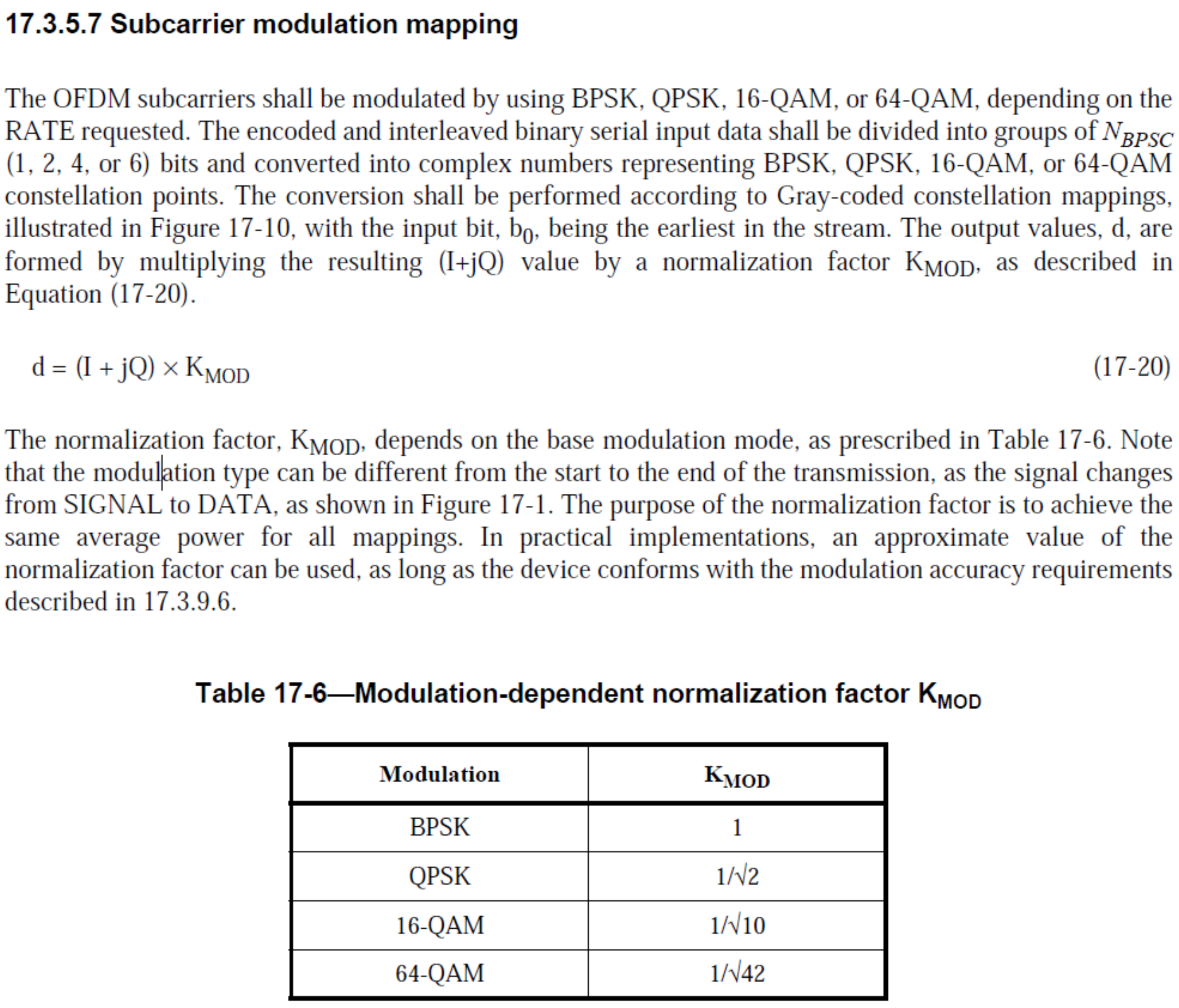
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 7 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>1/√2</td></tr>
<tr><td>16-QAM</td><td>1/√10</td></tr>
<tr><td>64-QAM</td><td>1/√42</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \tag{17-25}$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

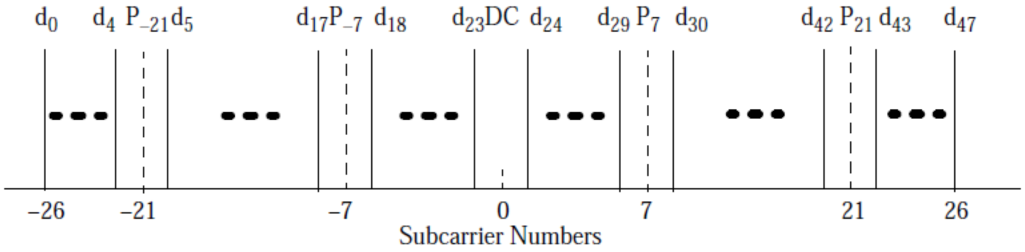


Figure 17-11—Subcarrier frequency allocation

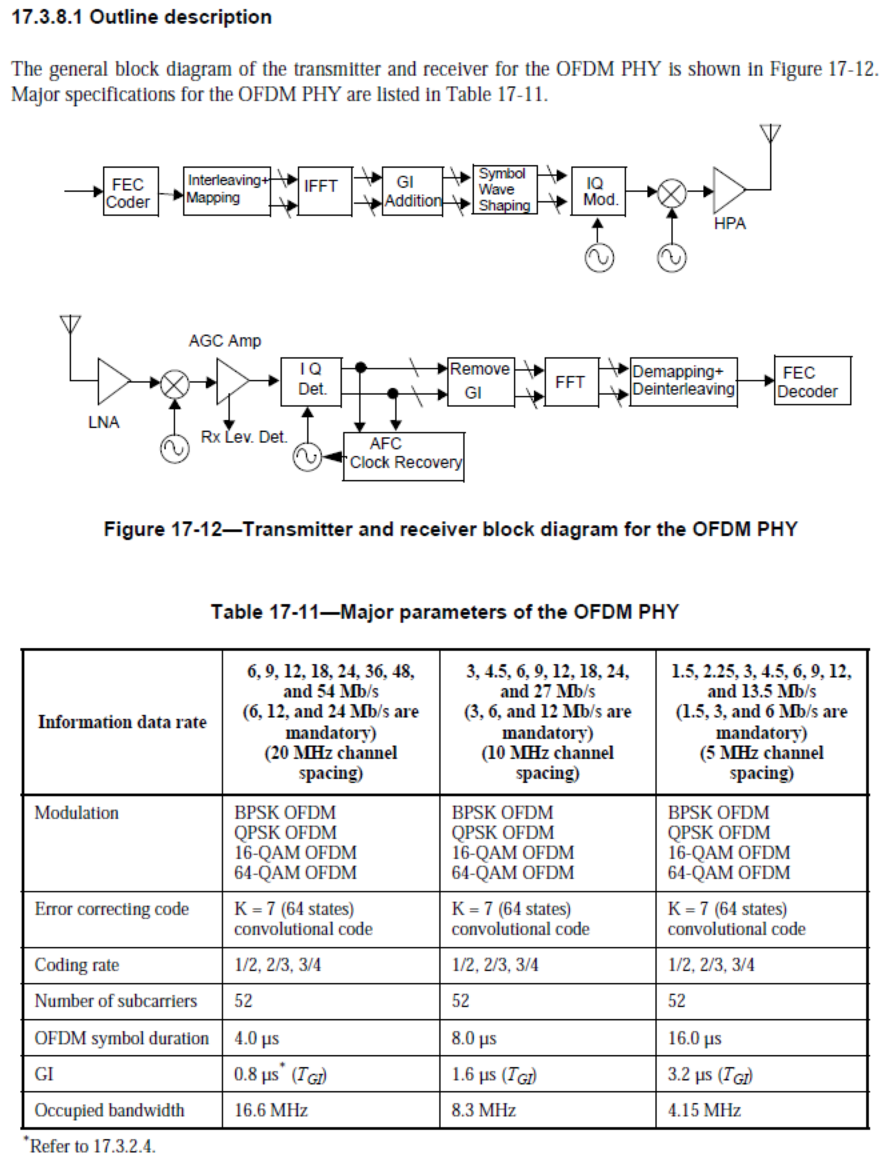
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \tag{17-26}$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 7 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See excerpt below



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

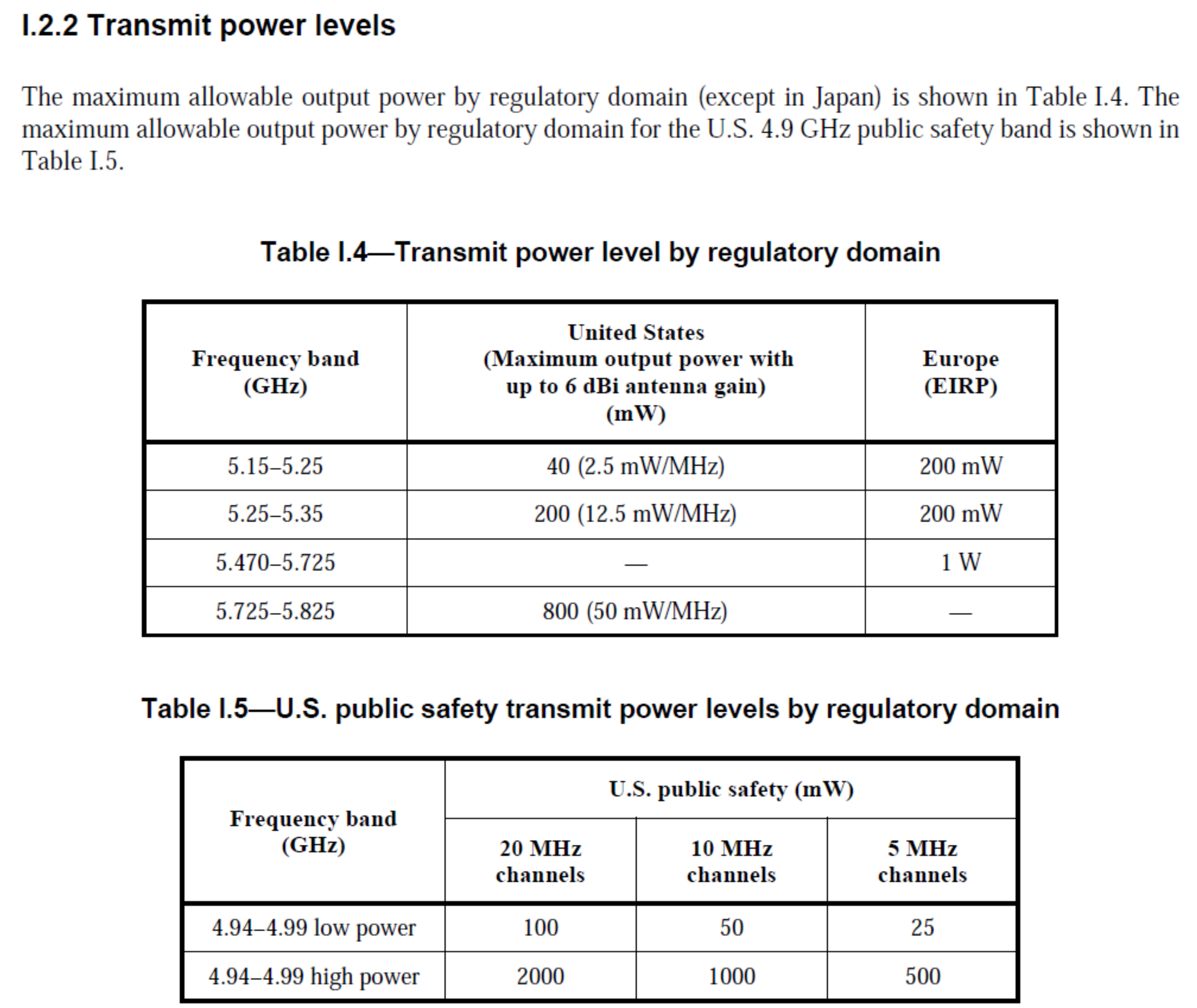
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

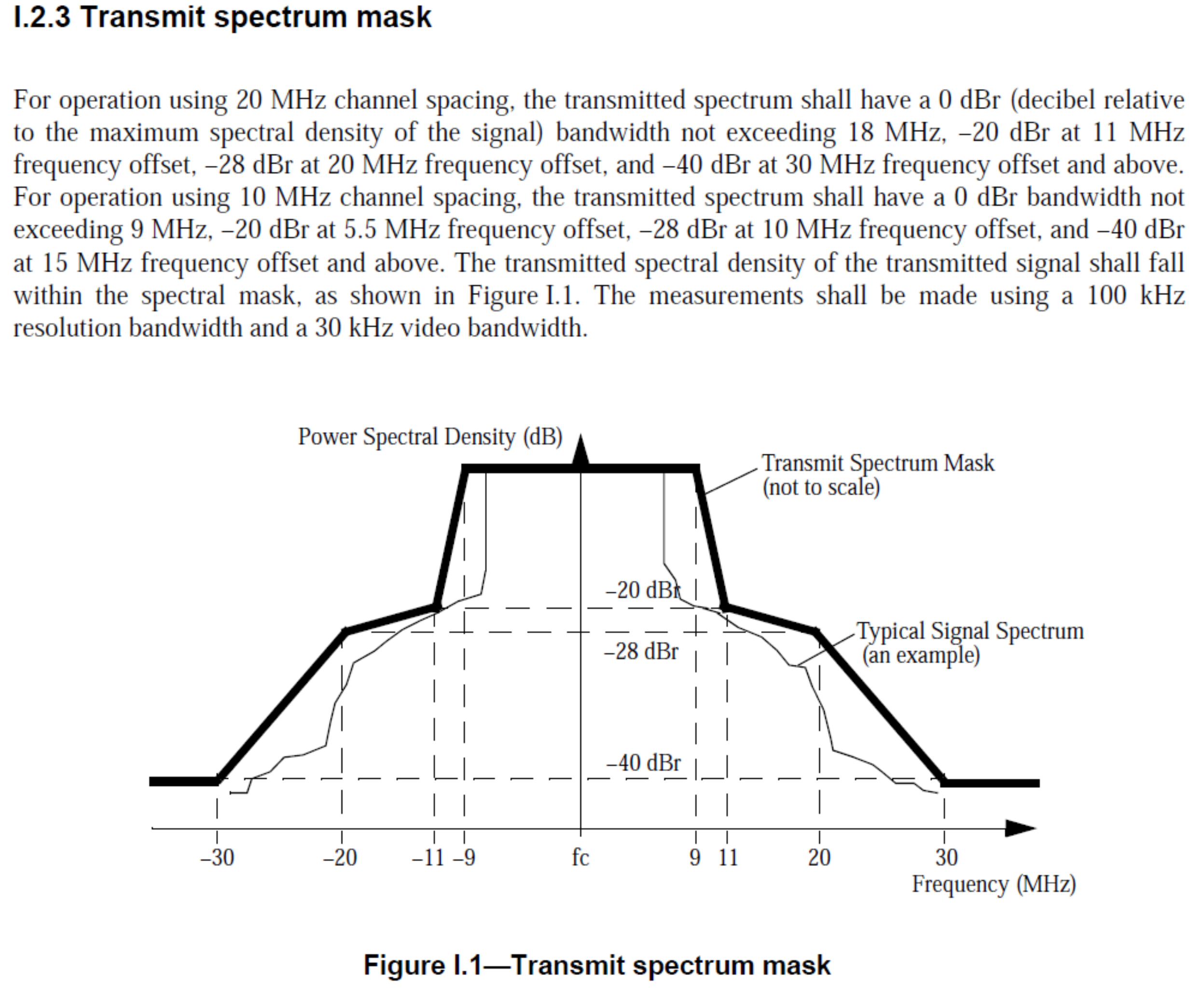
Table I.4—Transmit power level by regulatory domain

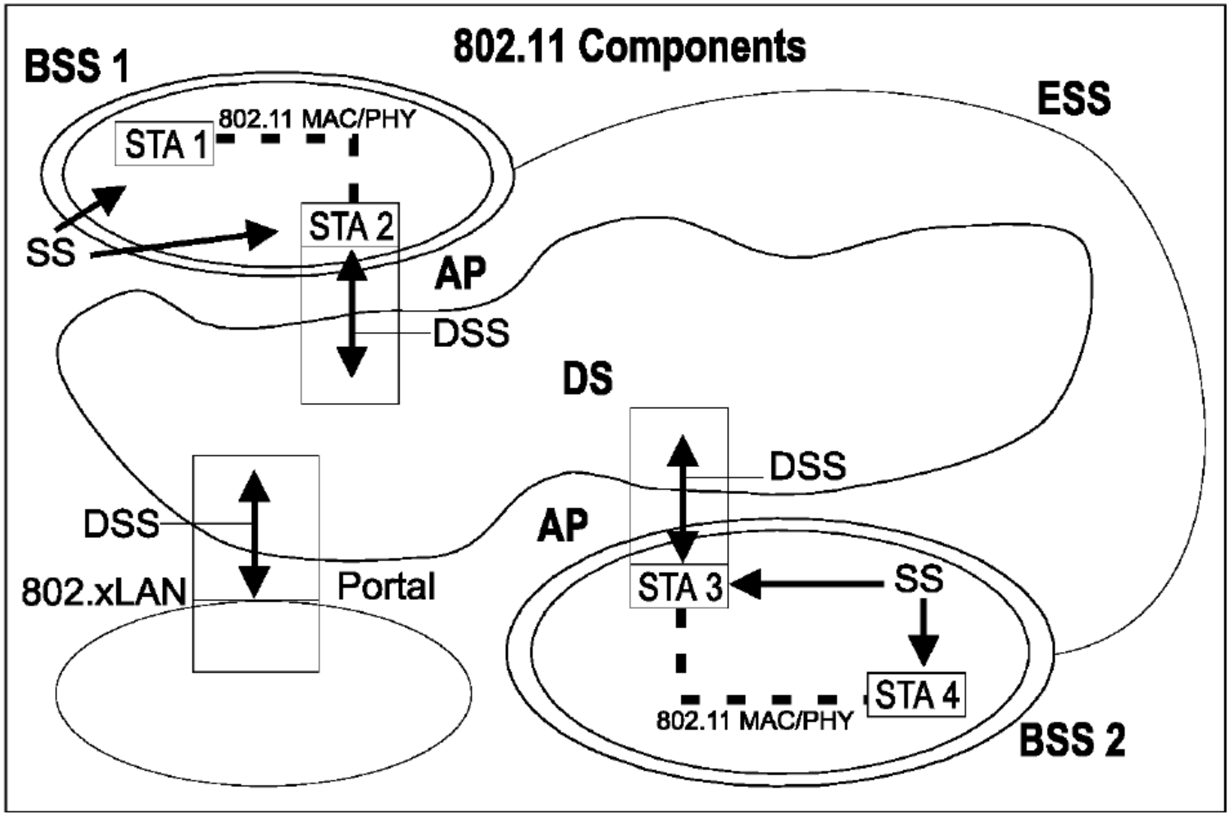
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

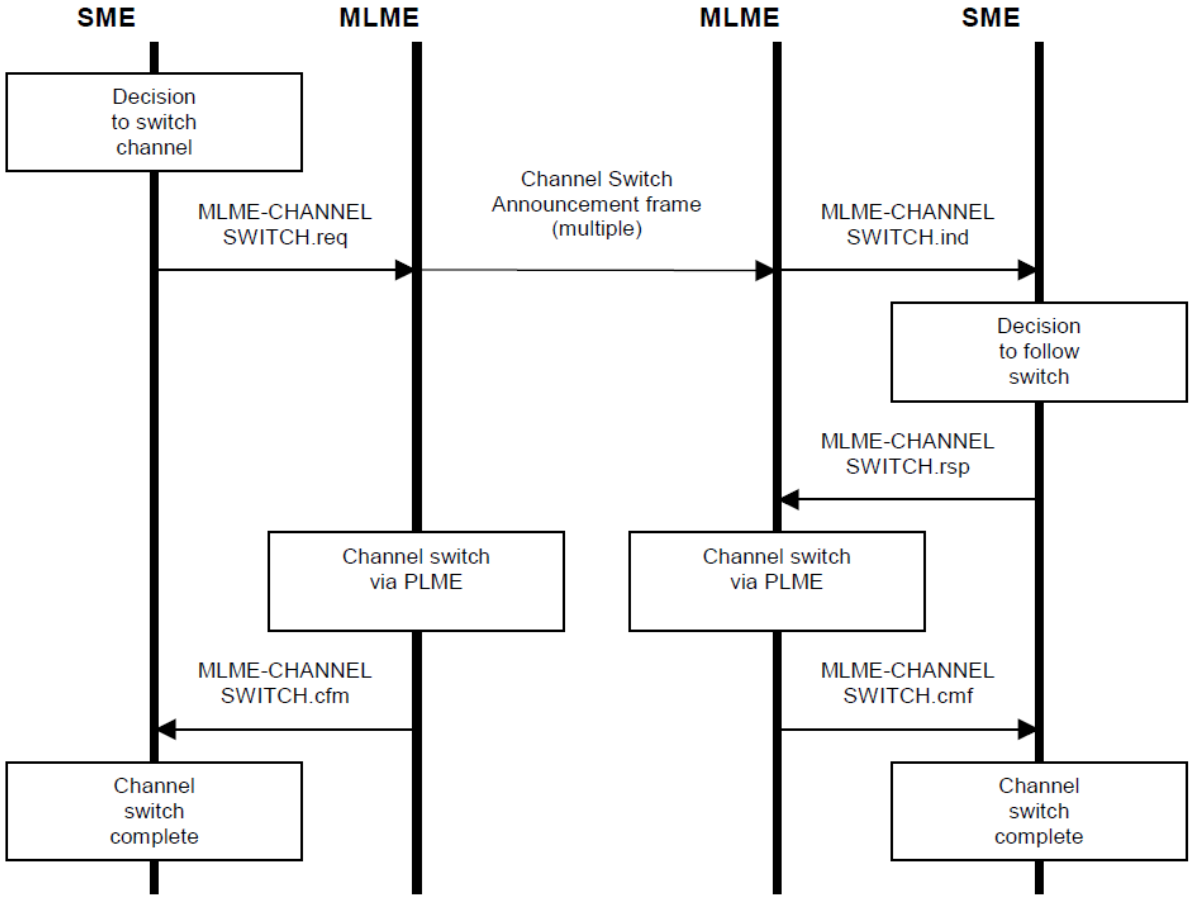
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 7 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007
[8.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[8.2] wherein the first information and the second information are from the same data stream.	802.11-2007 discloses “wherein the first information and the second information are from the same data stream.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

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	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts**

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	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2

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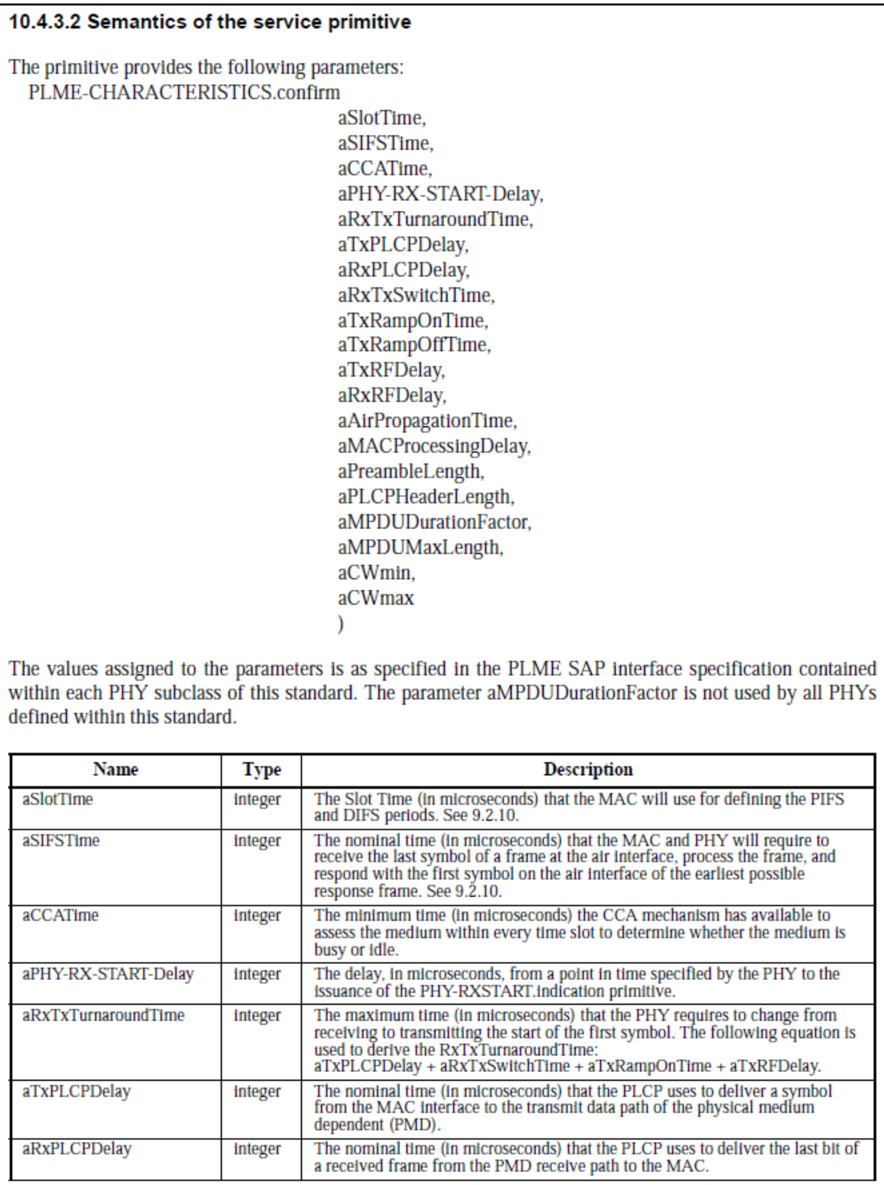
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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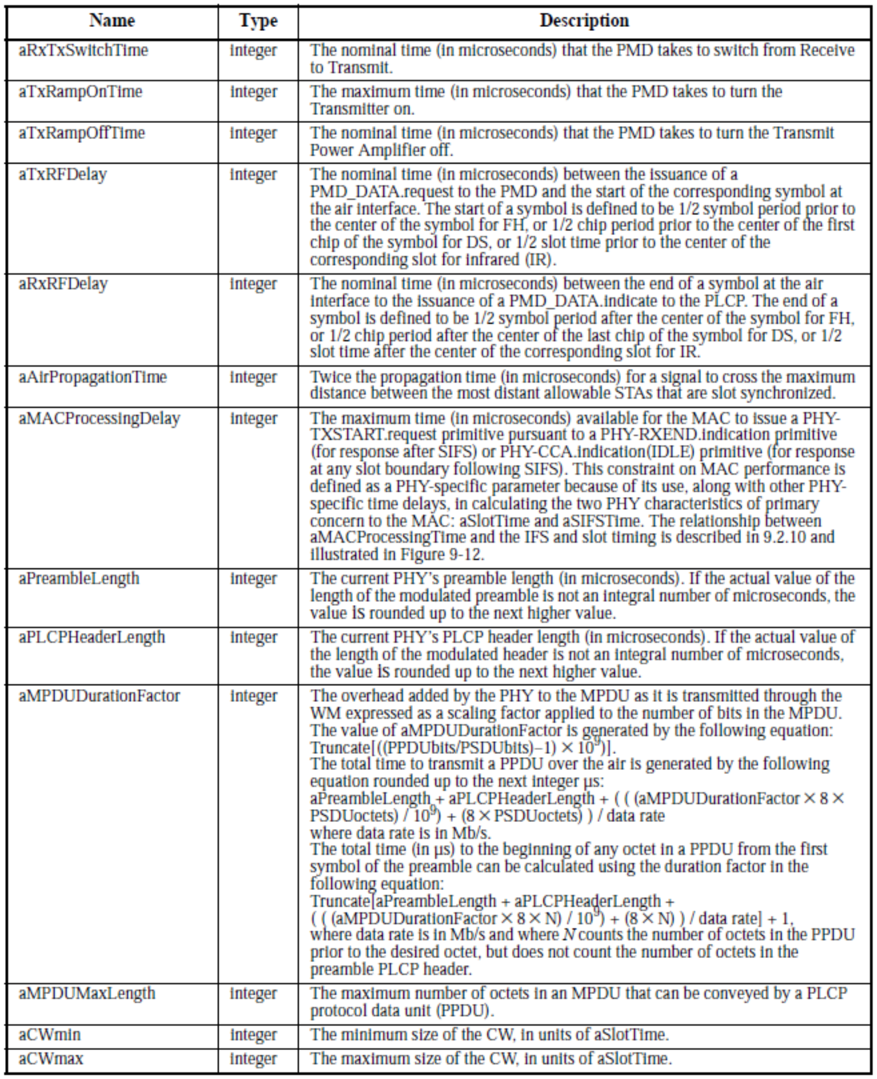

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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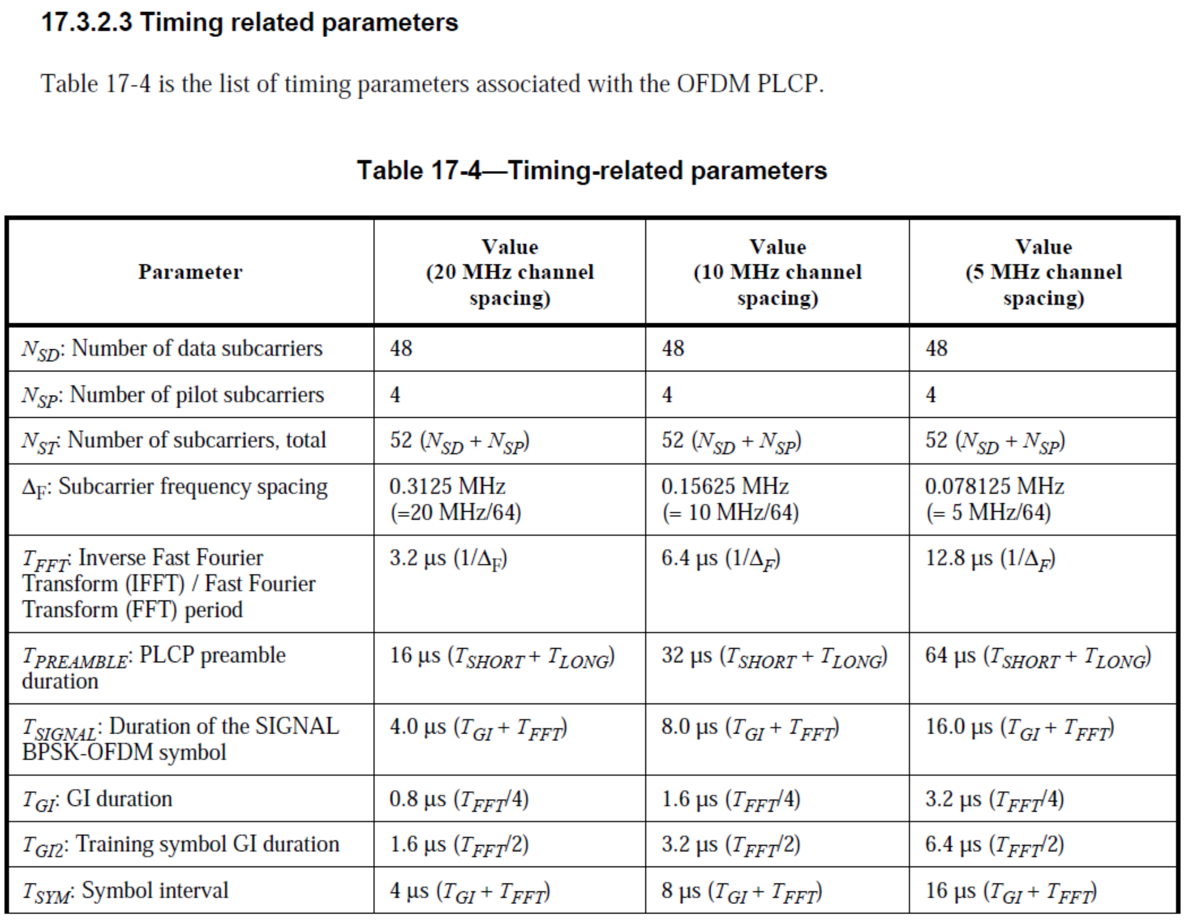
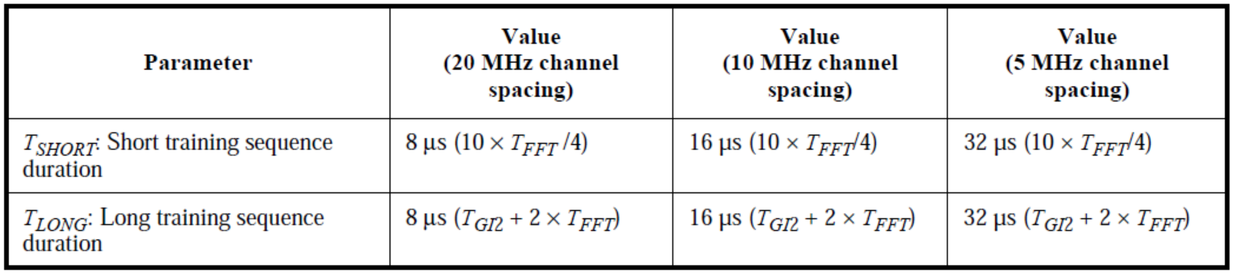
	

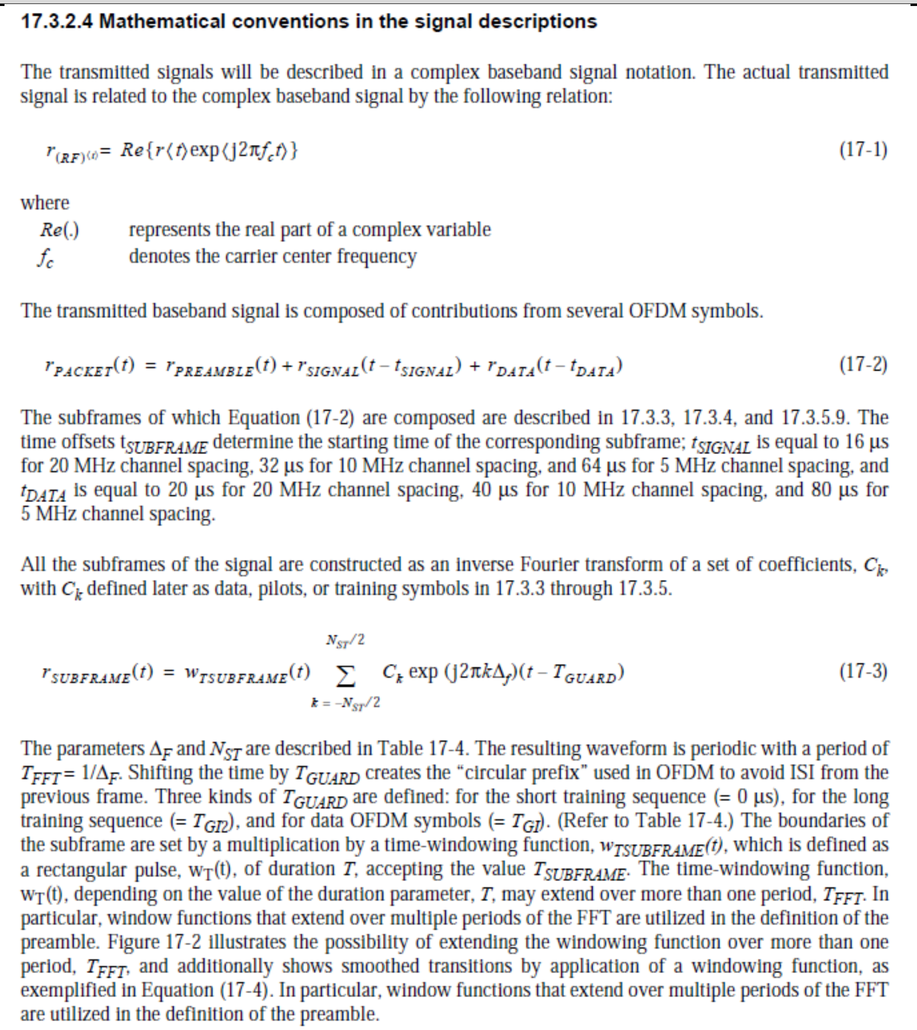
17.3.2.3 Timing related parameters

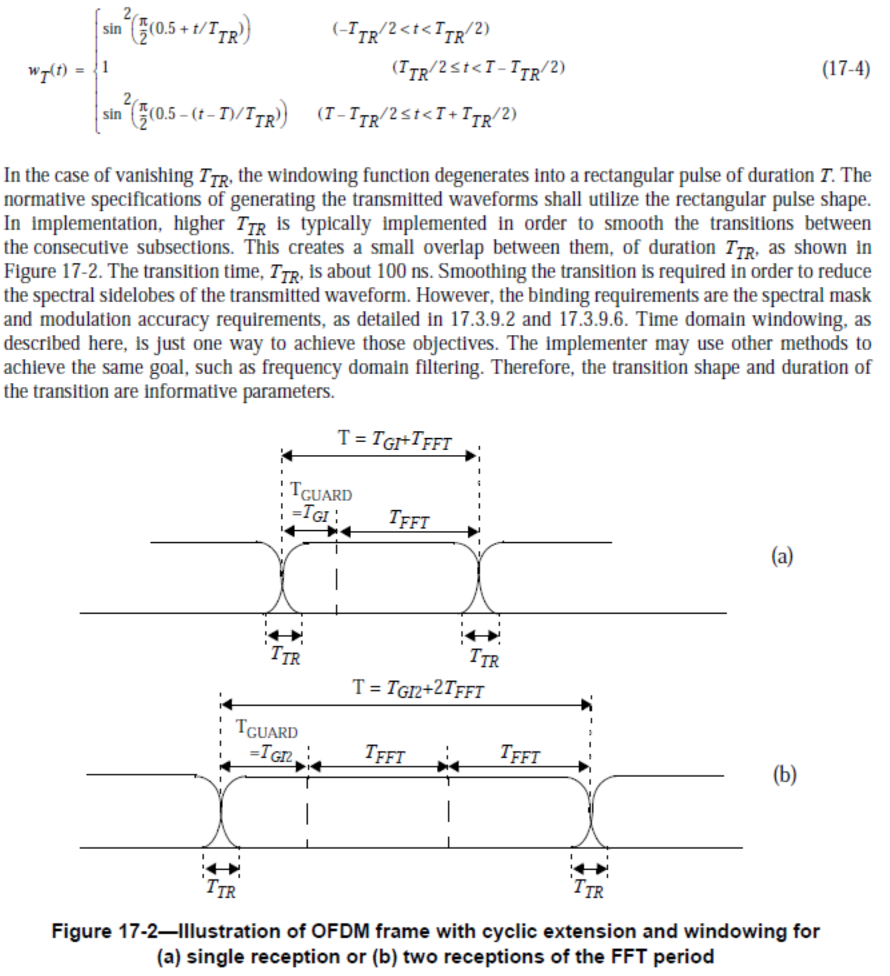
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

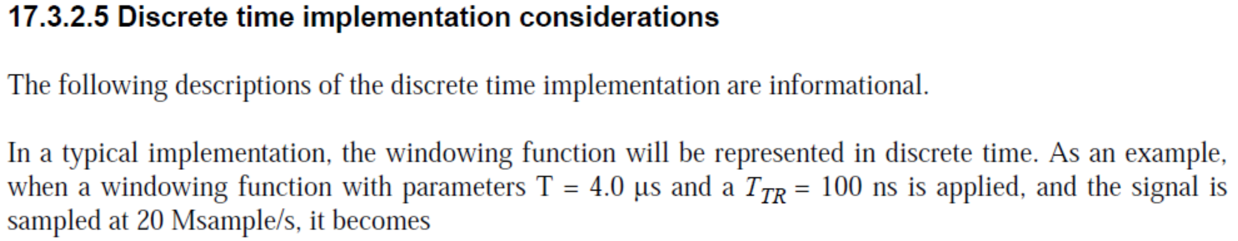
Table 17-4—Timing-related parameters

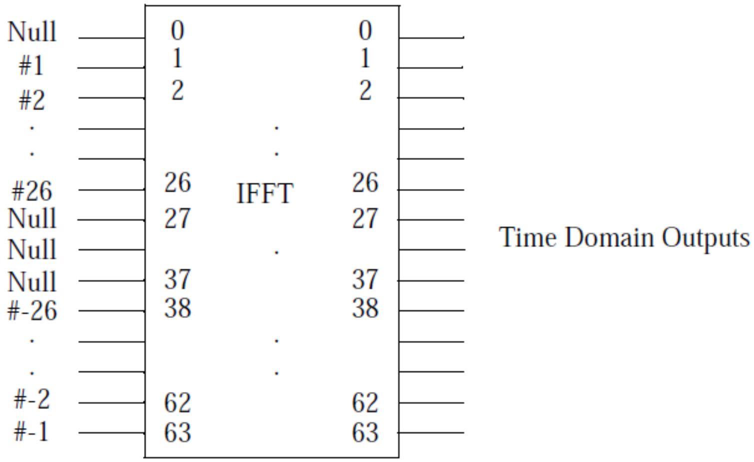
Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 8 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 8 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ (17-4) In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 8 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 8 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

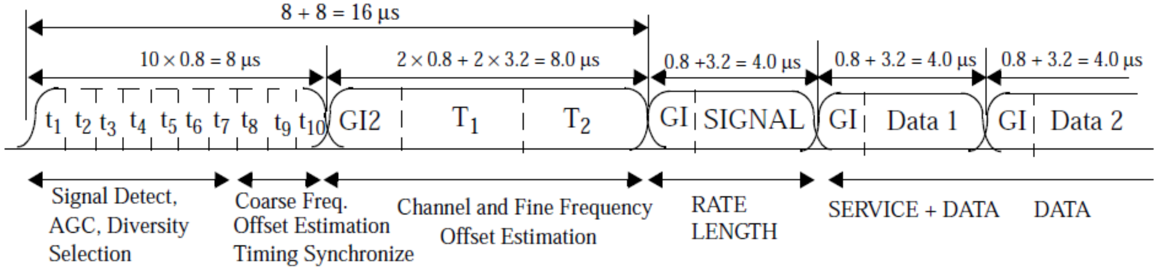
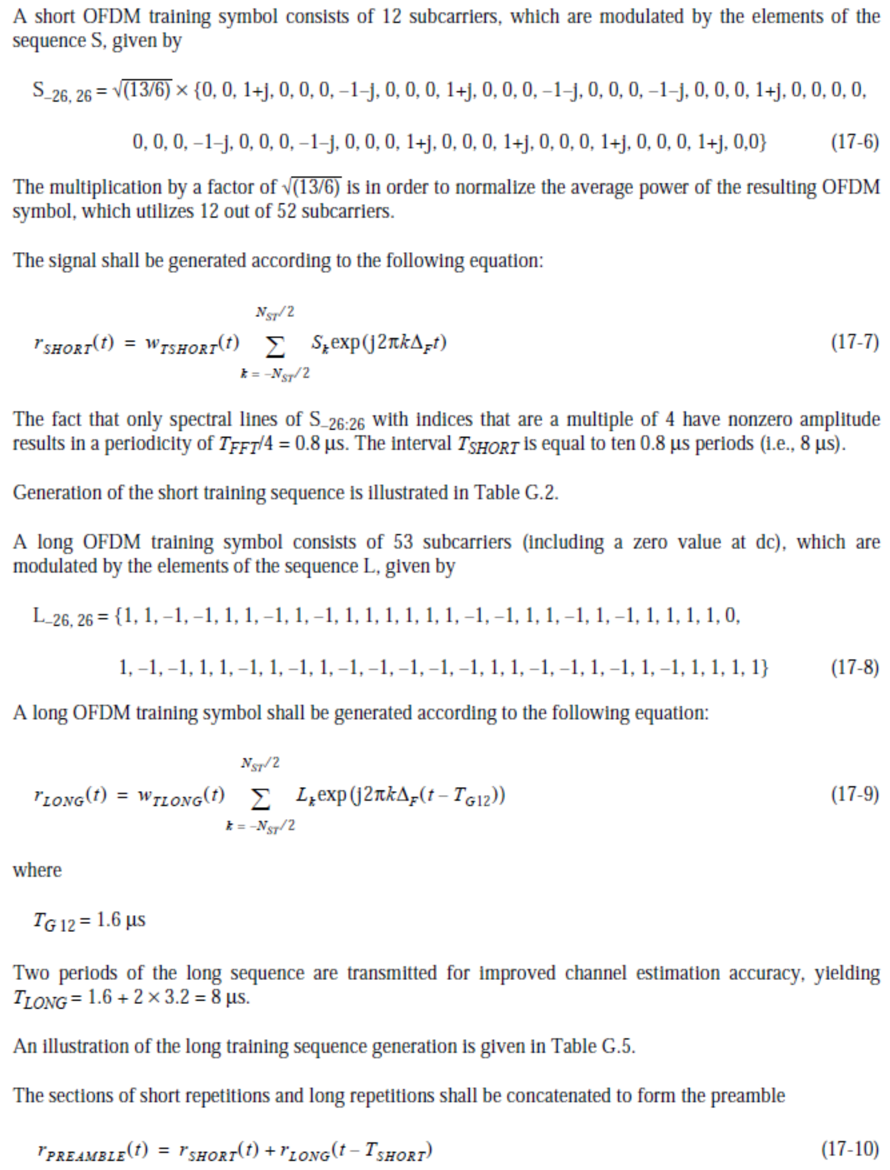


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

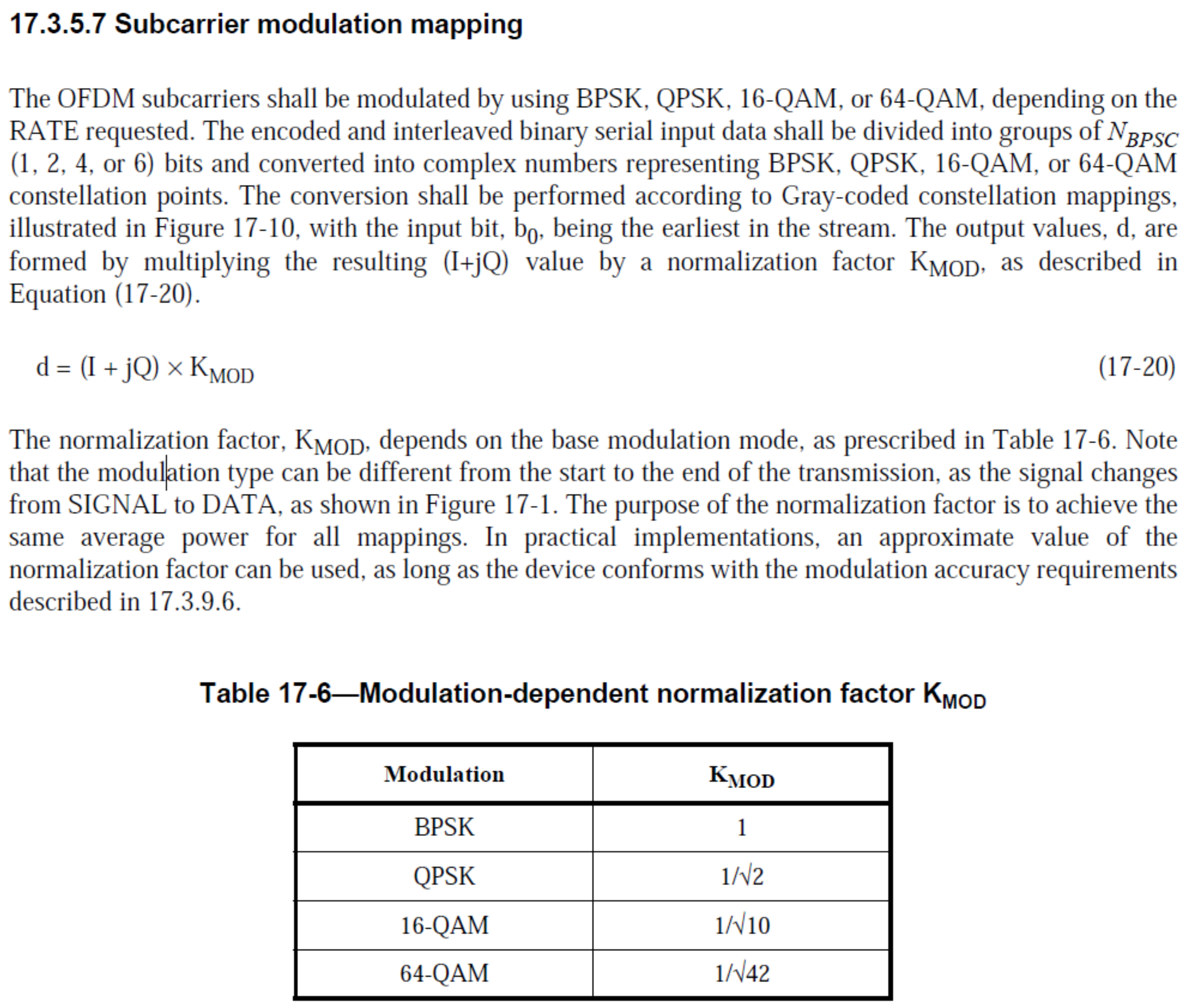
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 8 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \qquad (17\text{-}21)$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n} \exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1} \sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t - T_{GI})) \right) \qquad (17\text{-}22)$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \qquad (17\text{-}23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,\,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \qquad (17\text{-}24)$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \qquad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

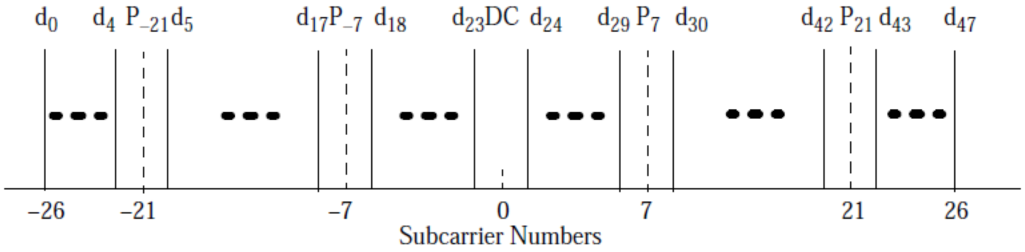


Figure 17-11—Subcarrier frequency allocation

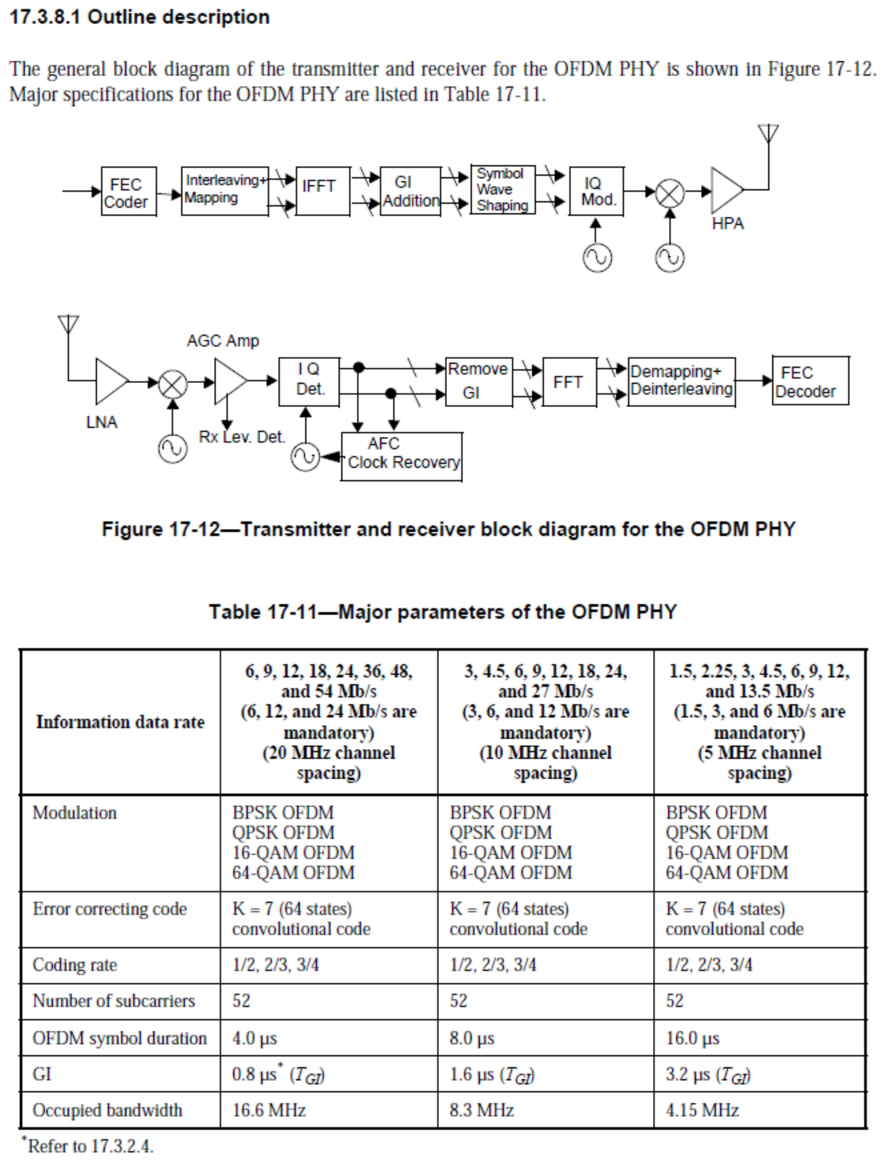
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

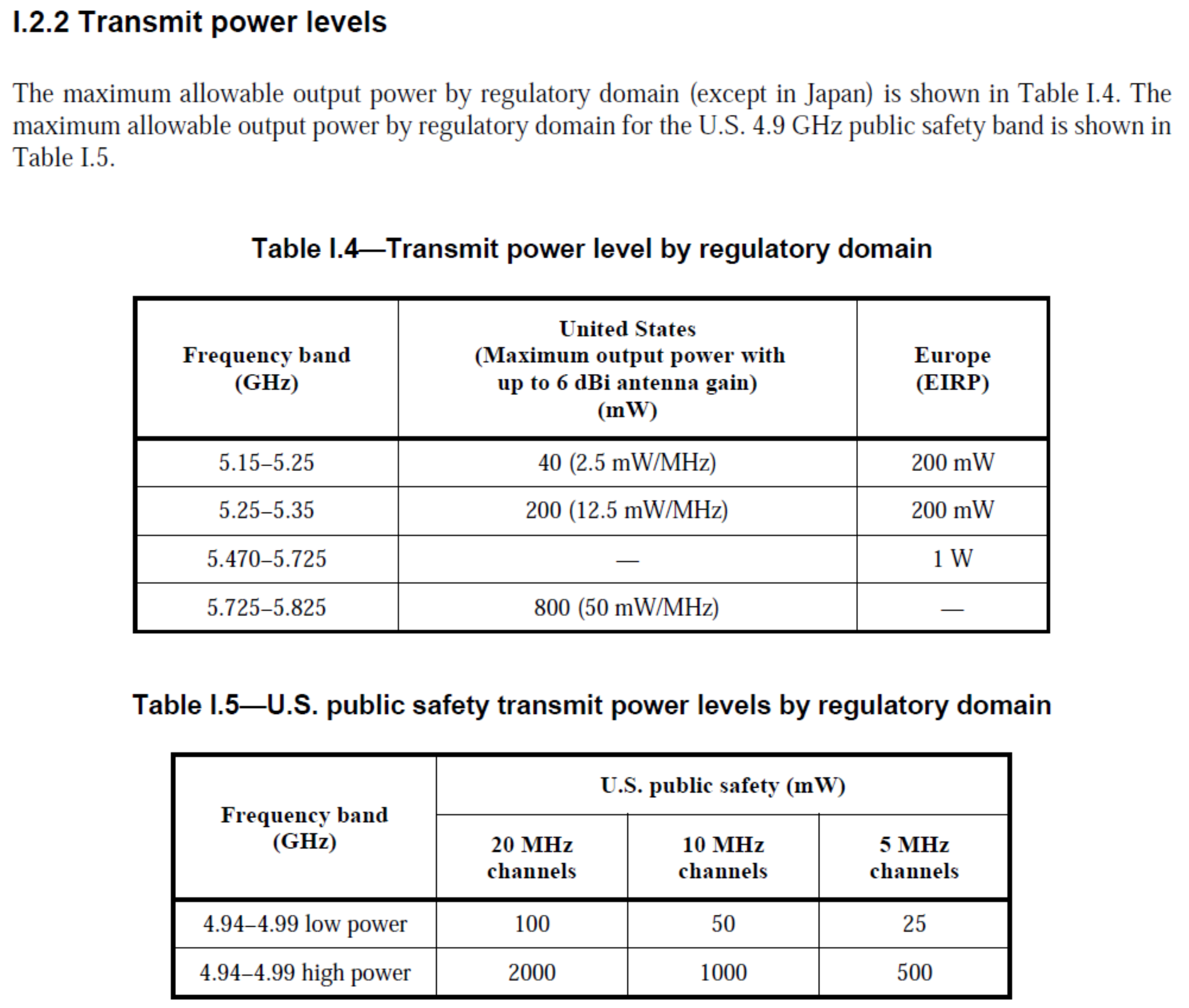
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

Table I.4—Transmit power level by regulatory domain

Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

<table>
<tr><th>Claim 8 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

I.2.3 Transmit spectrum mask

For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

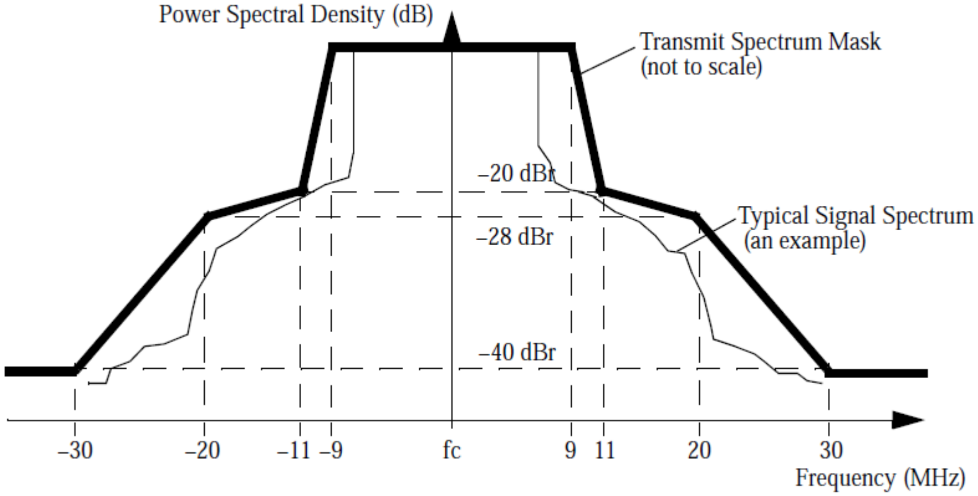
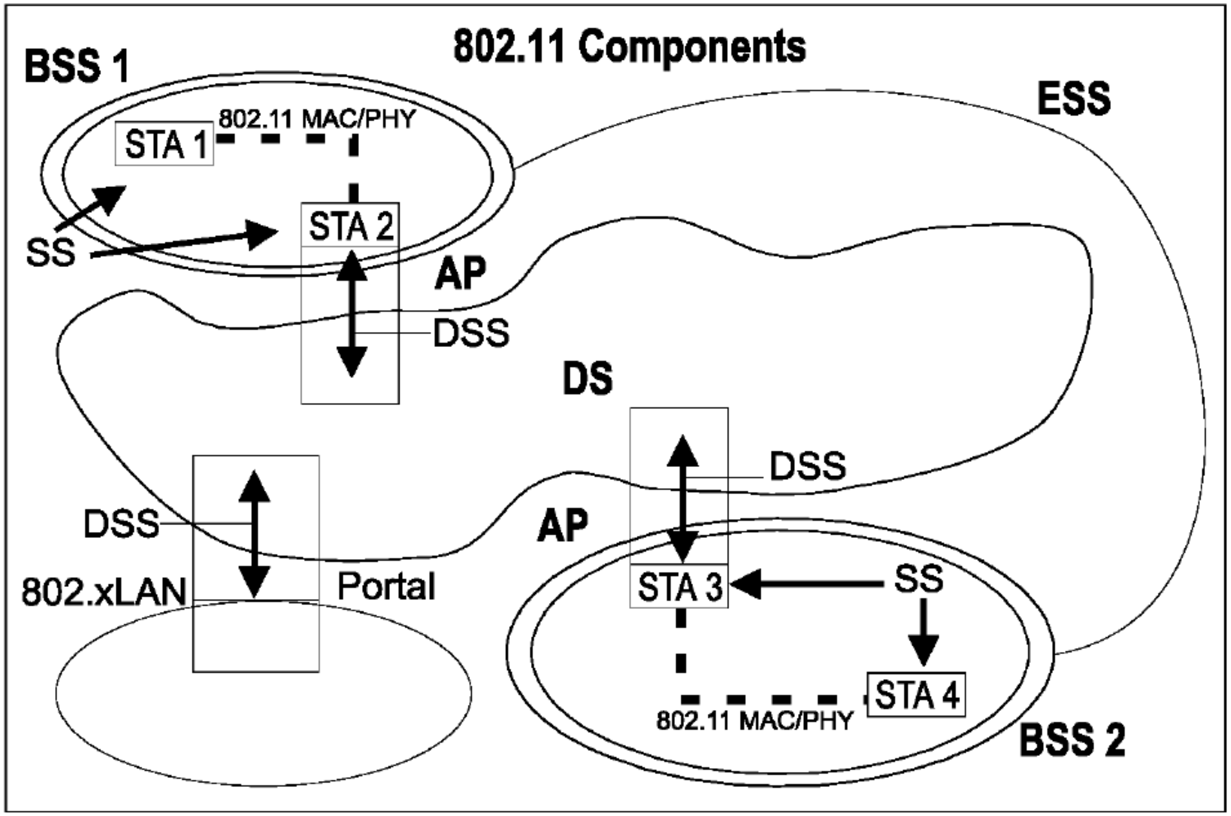
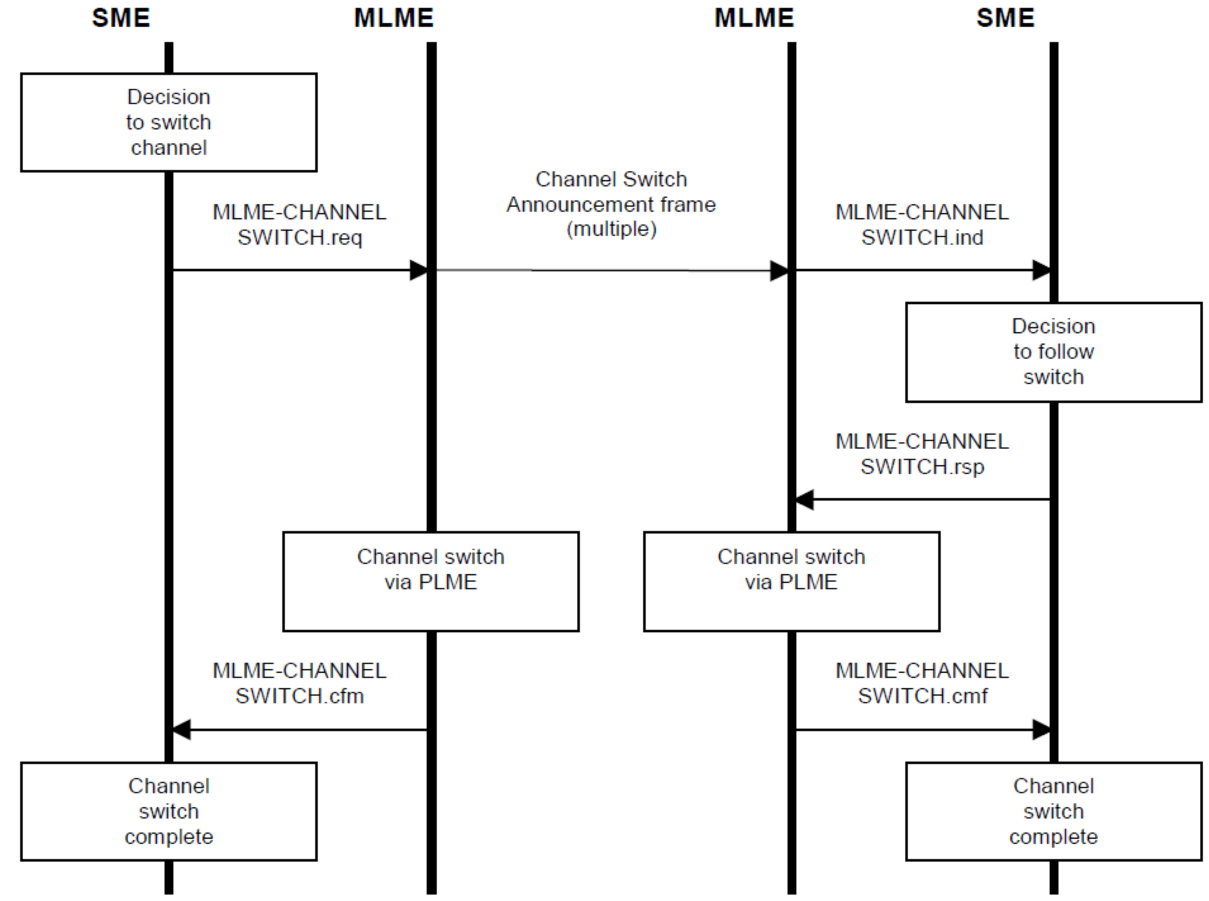


Figure I.1—Transmit spectrum mask

See, e.g., 802.11-2007 § I.2.3

</td></tr>
</table>

Claim 8 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 8 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
[9.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[9.2] wherein first information and second information comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first frequency range and a second symbol is transmitted during the first time slot across the second frequency range, and wherein a third symbol is transmitted during a second time slot across the first frequency range and a fourth symbol is transmitted during the second time slot across a second frequency range.	802.11-2007 discloses “wherein first information and second information comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first frequency range and a second symbol is transmitted during the first time slot across the second frequency range, and wherein a third symbol is transmitted during a second time slot across the first frequency range and a fourth symbol is transmitted during the second time slot across a second frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly

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	communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.

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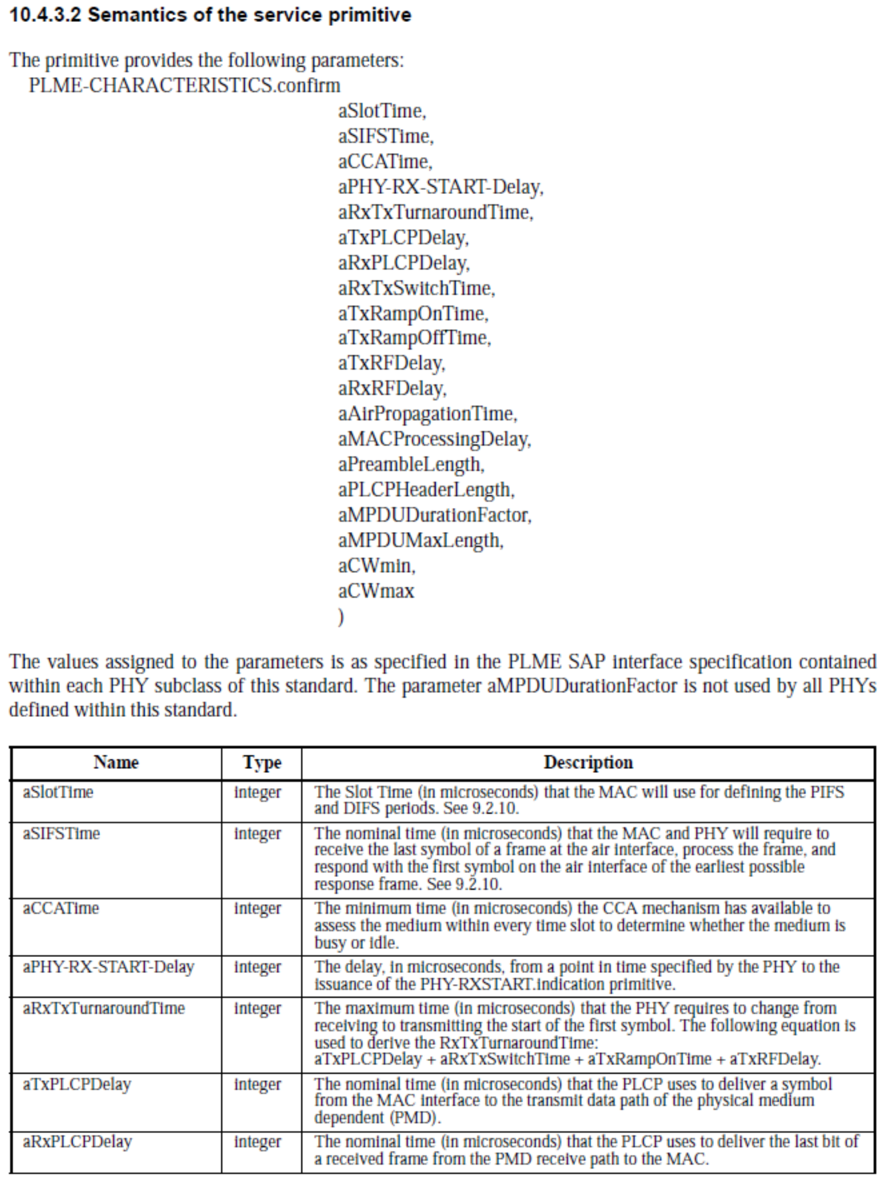
	See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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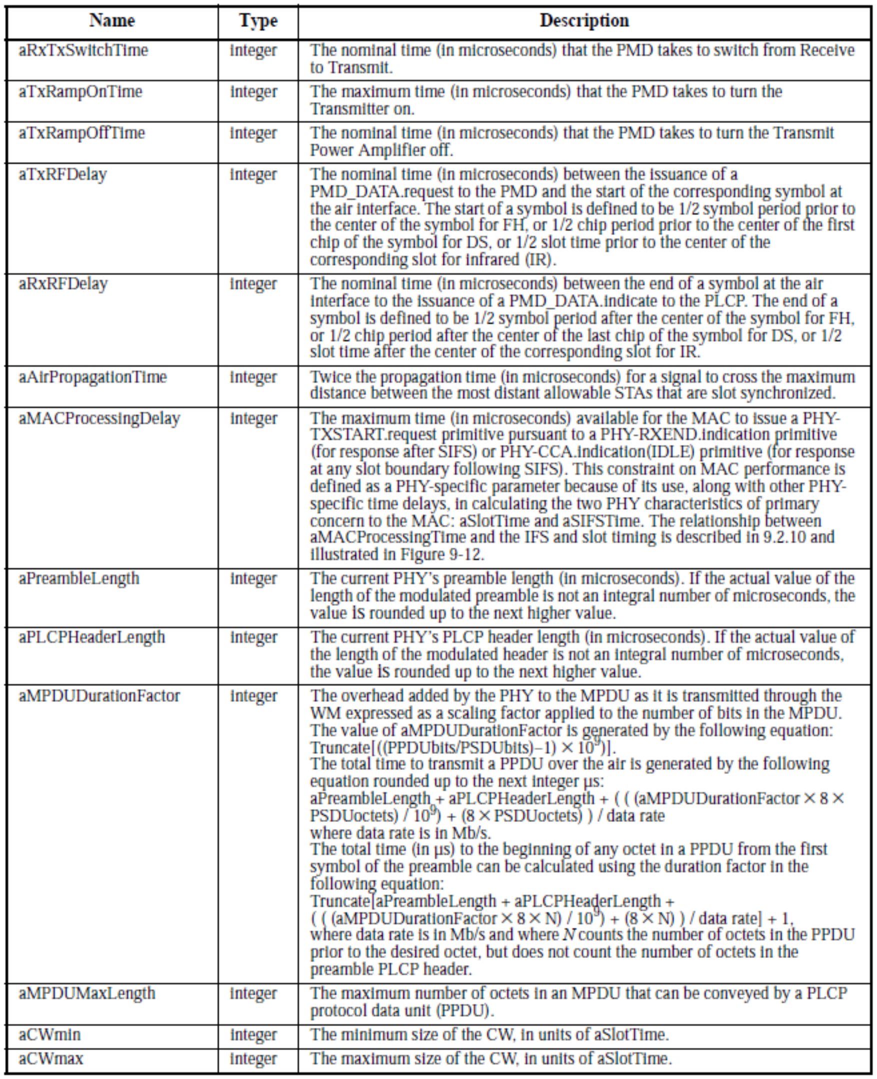

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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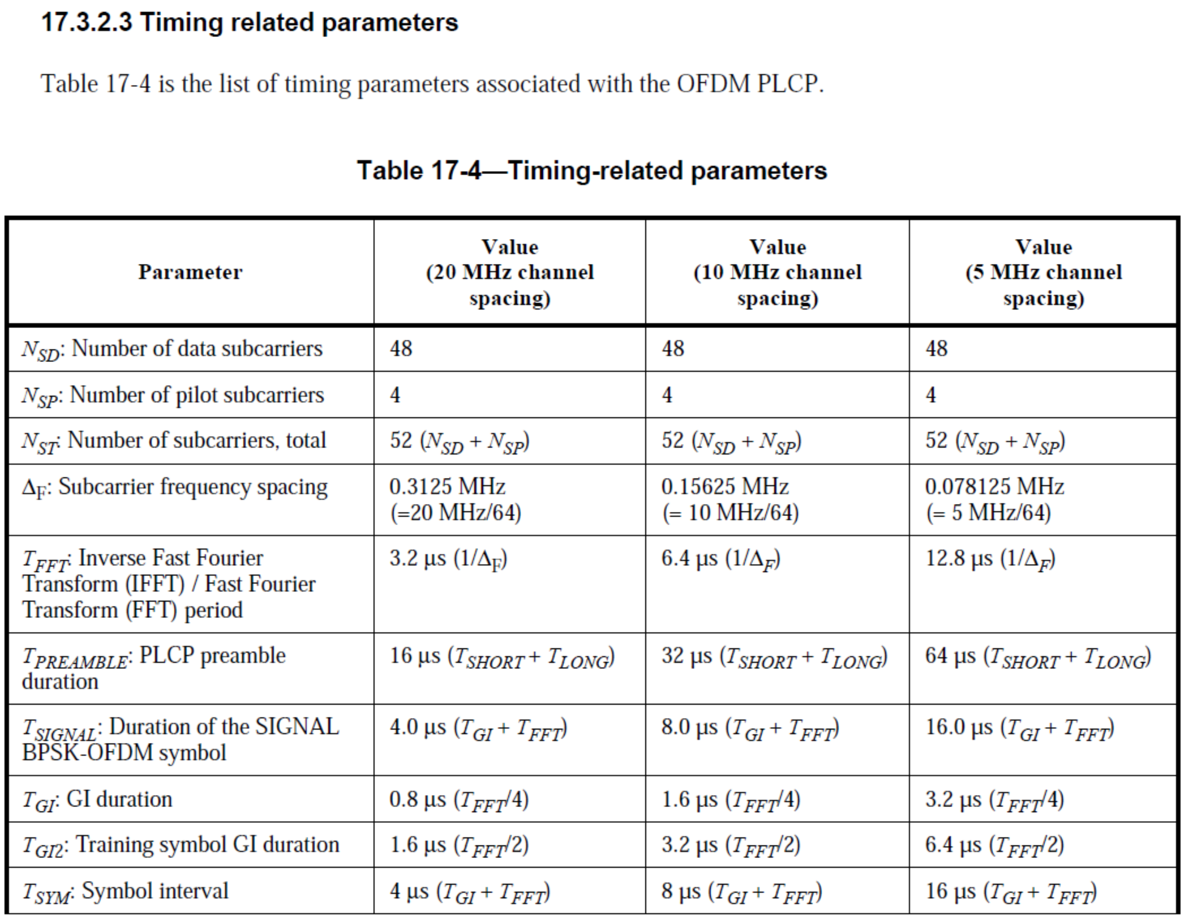
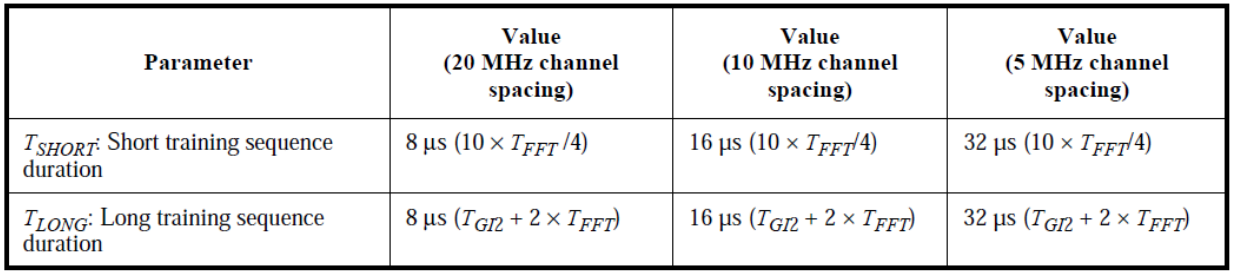
	

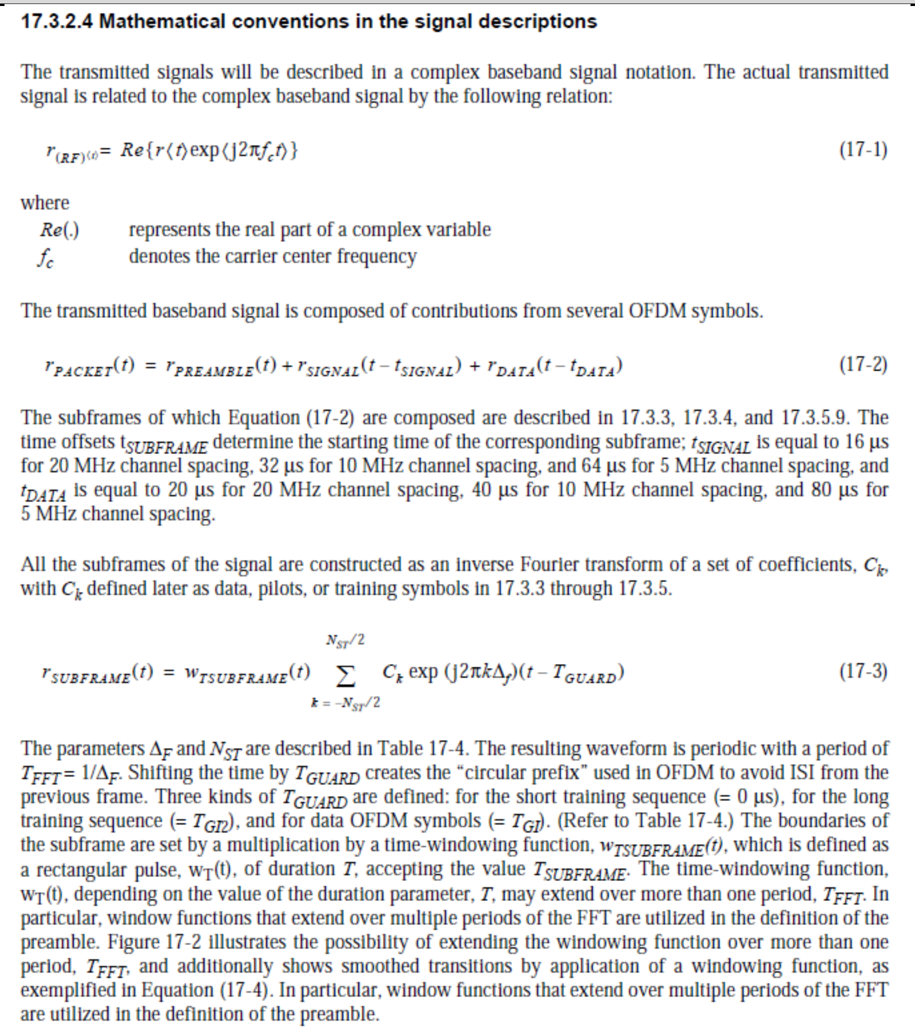
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 9 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 μs (10 × T_{FFT} /4)</td><td>16 μs (10 × T_{FFT}/4)</td><td>32 μs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 μs (T_{GI2} + 2 × T_{FFT})</td><td>16 μs (T_{GI2} + 2 × T_{FFT})</td><td>32 μs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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<tr><th>Claim 9 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$$

In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.

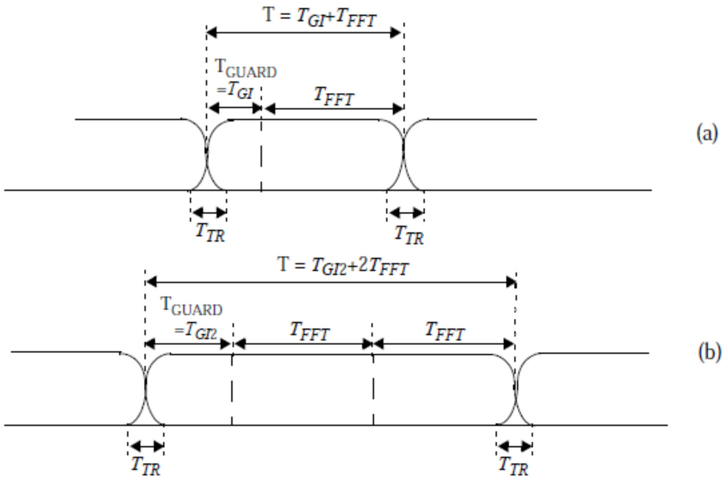
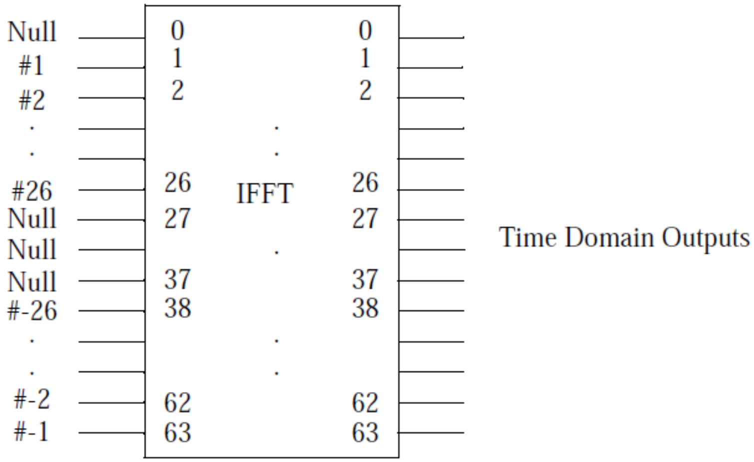


Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period

See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)
</td></tr>
</table>

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 9 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 9 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

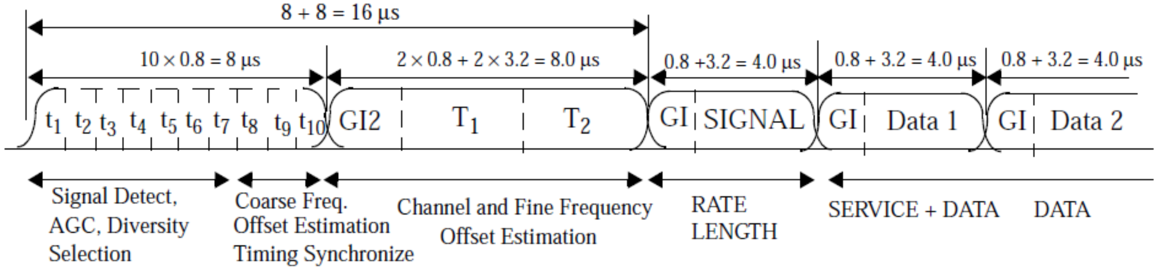
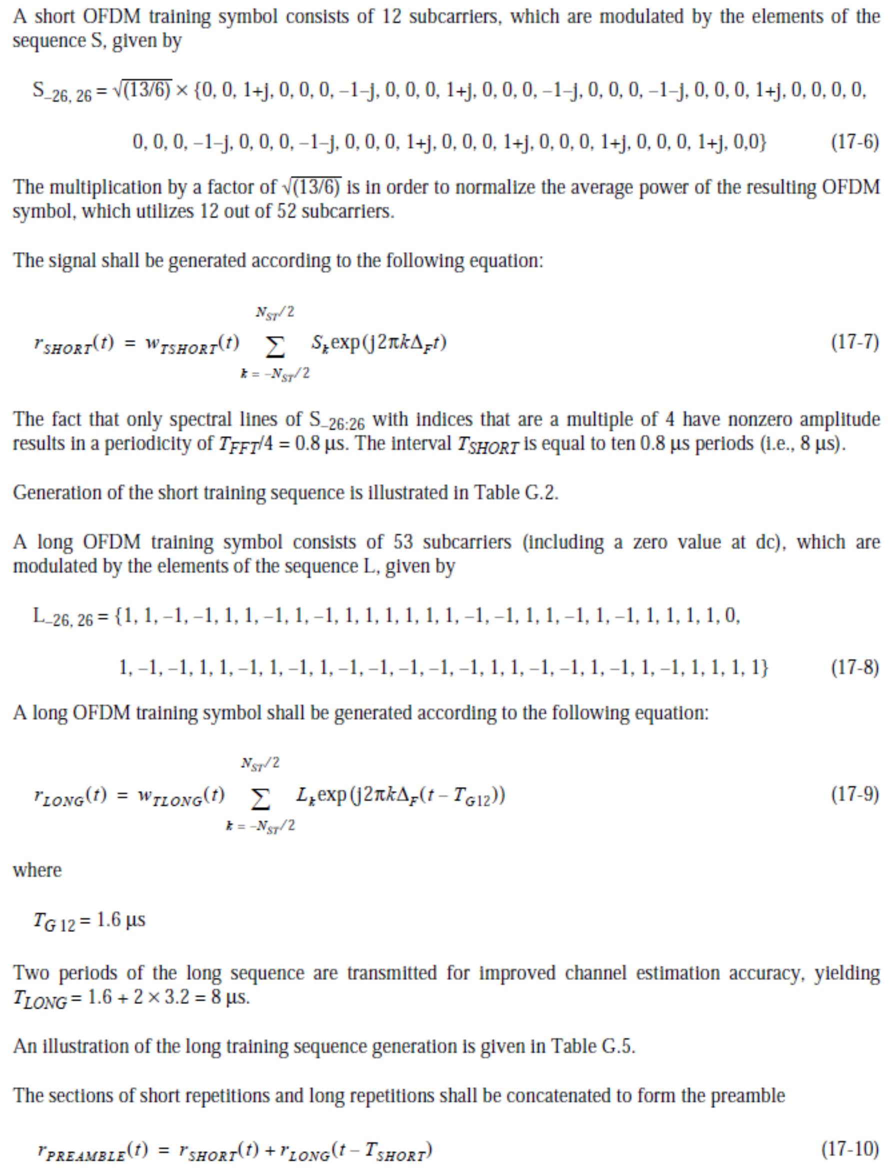


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

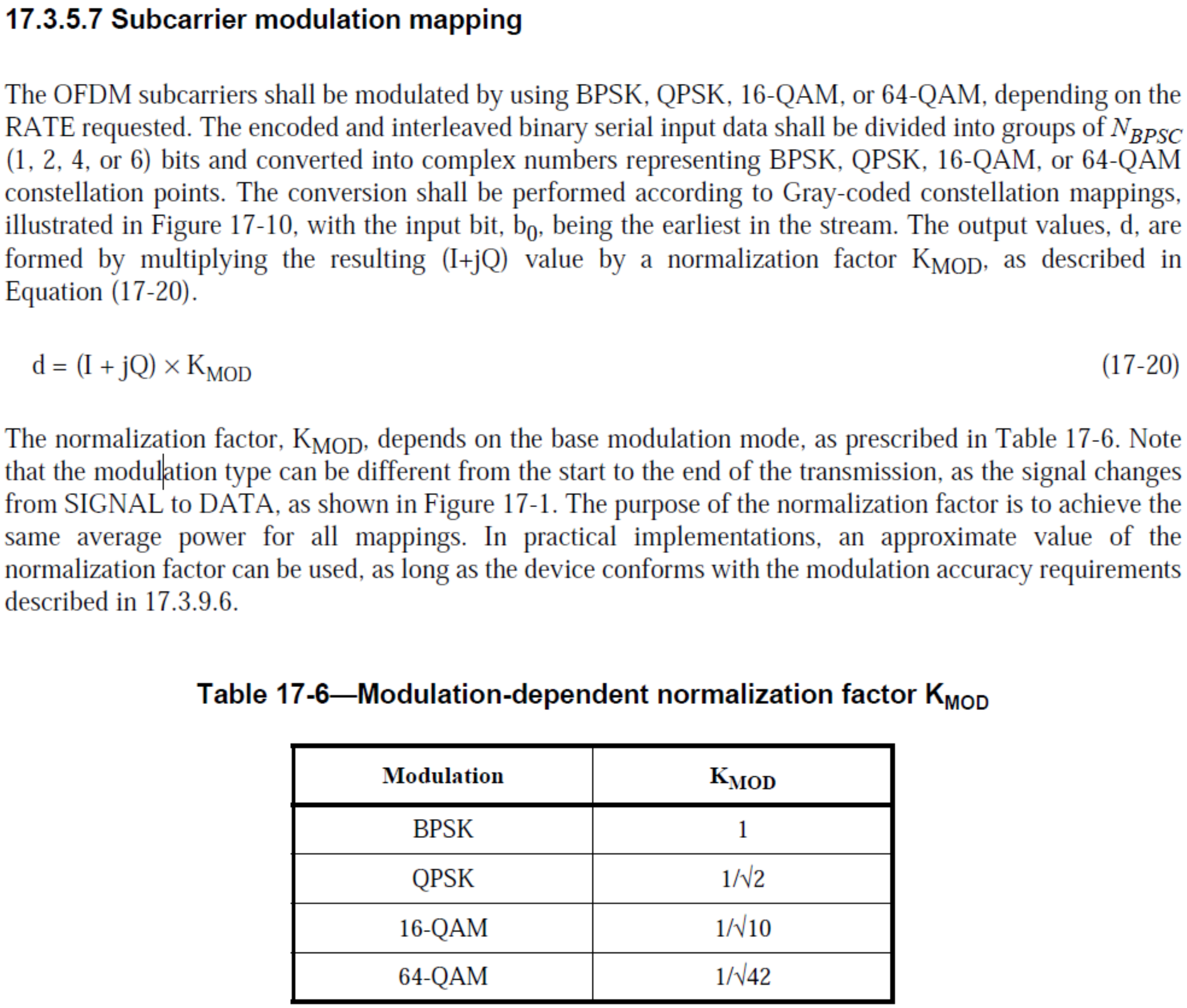
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 9 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k + N_{SD} \times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$P_{-26,26} = \{0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

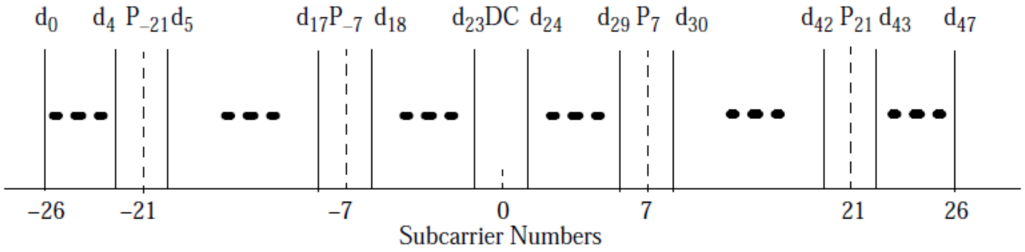


Figure 17-11—Subcarrier frequency allocation

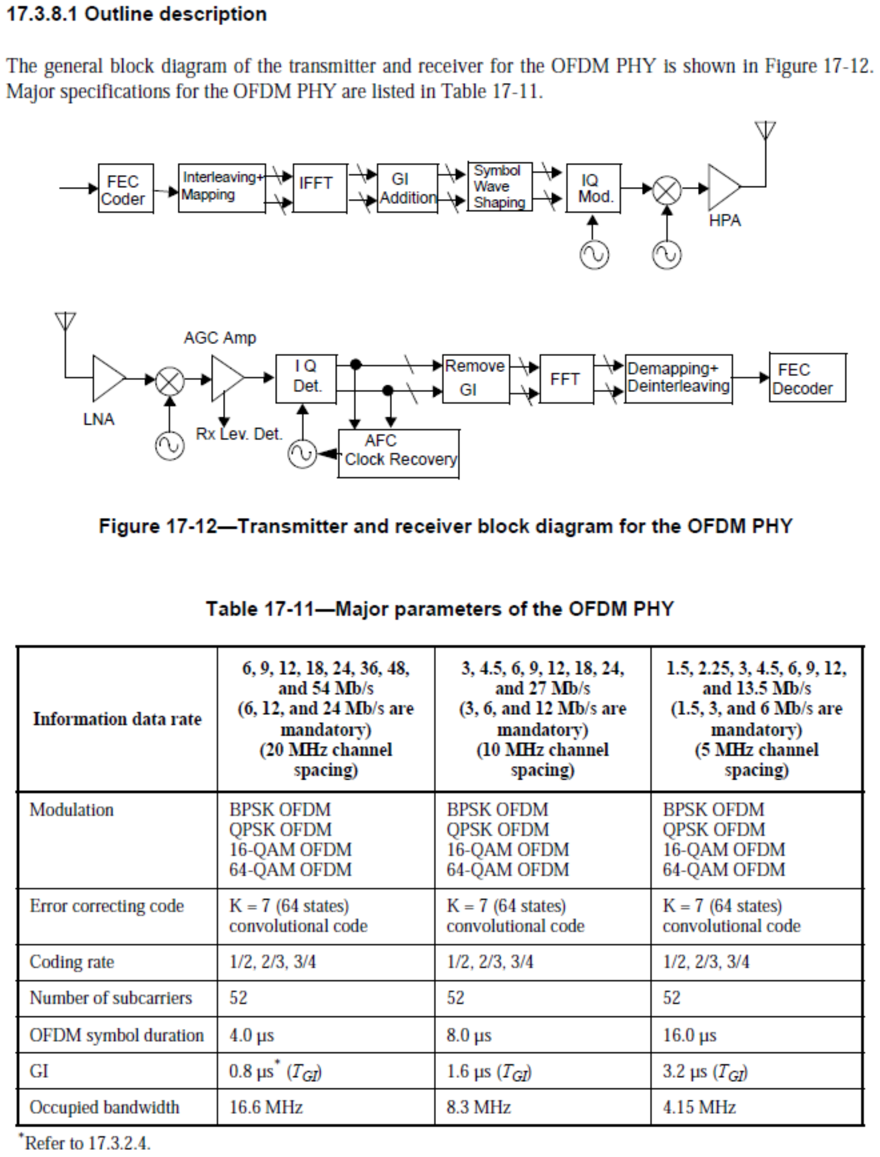
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 9 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

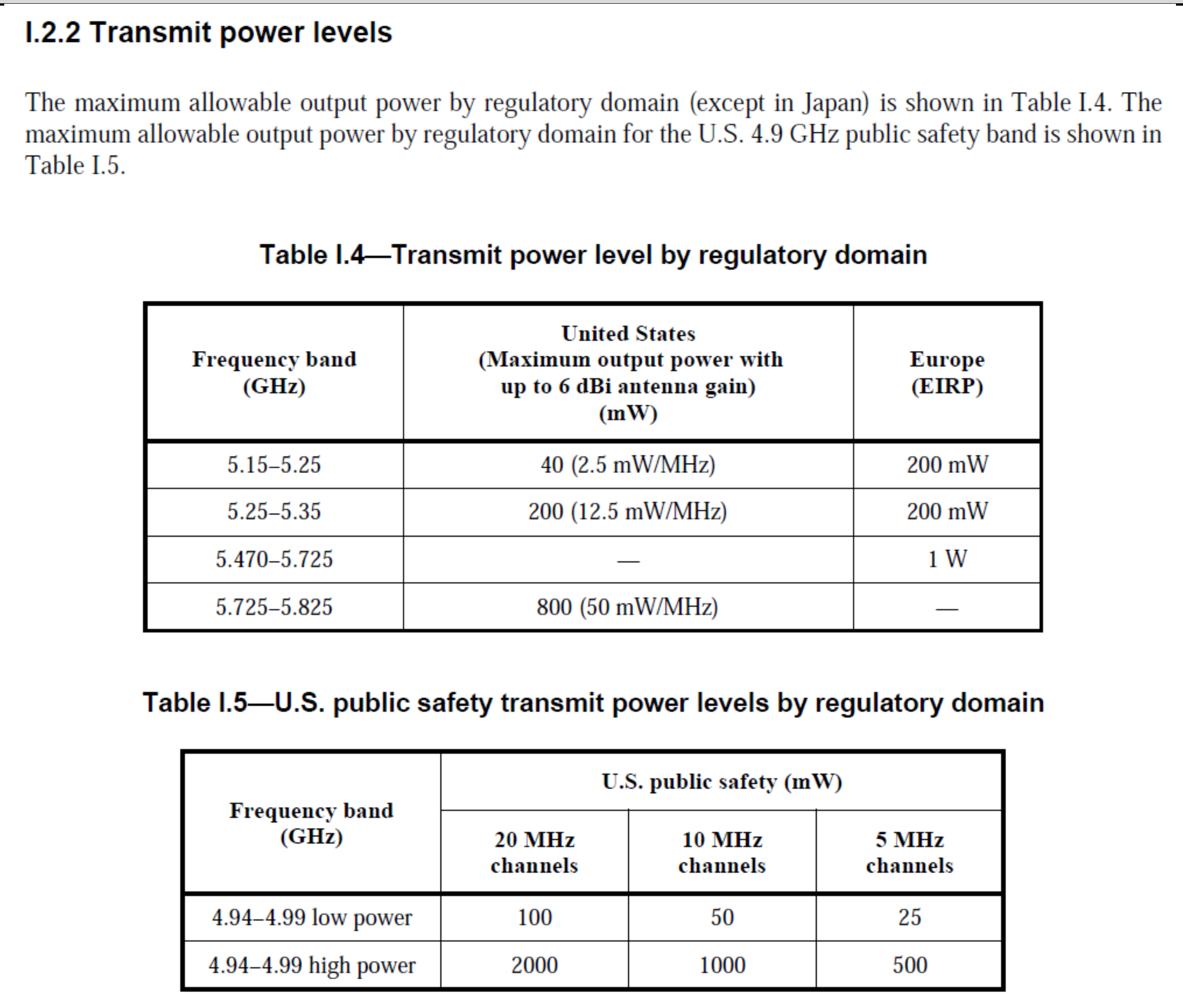
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 9 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 See, e.g., 802.11-2007 § I.2.2

I.2.2 Transmit power levels

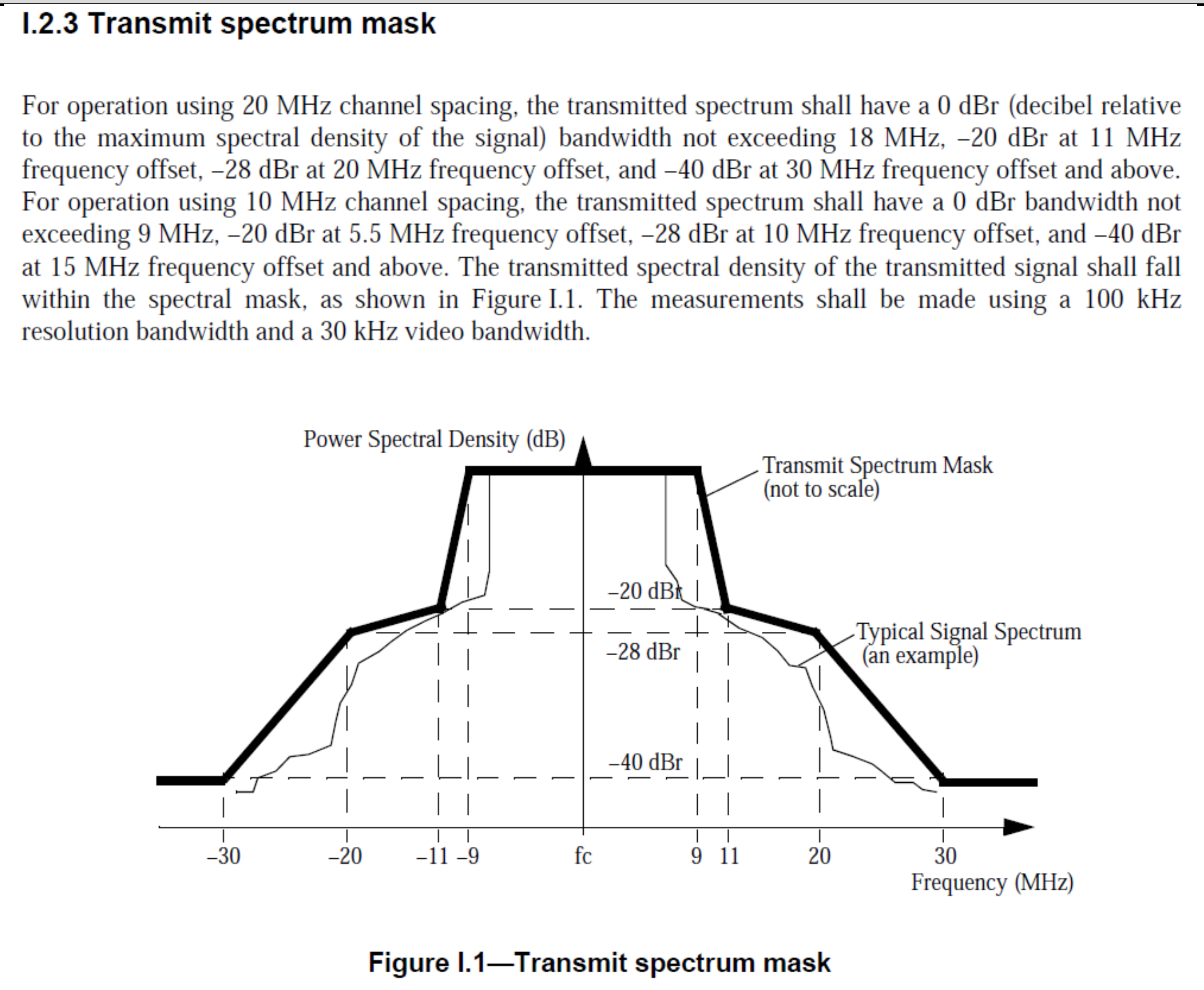
The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

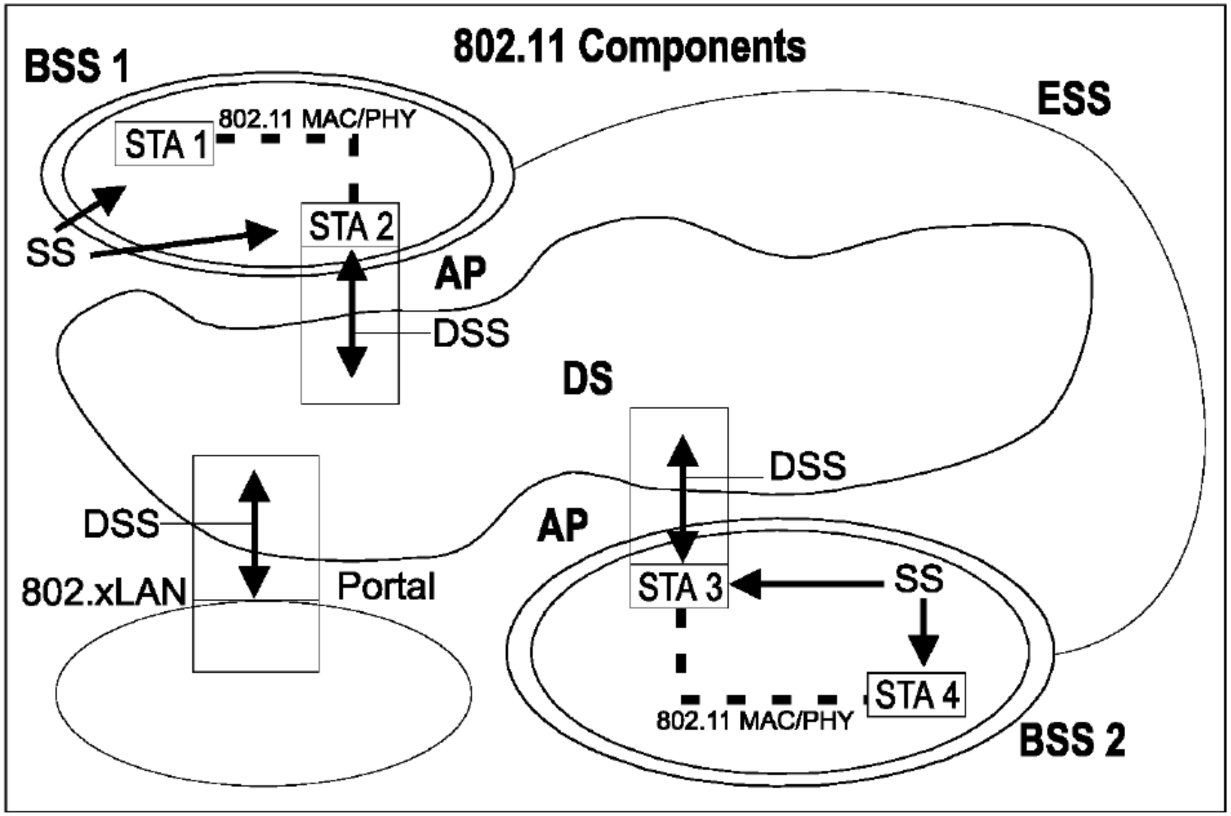
Table I.4—Transmit power level by regulatory domain

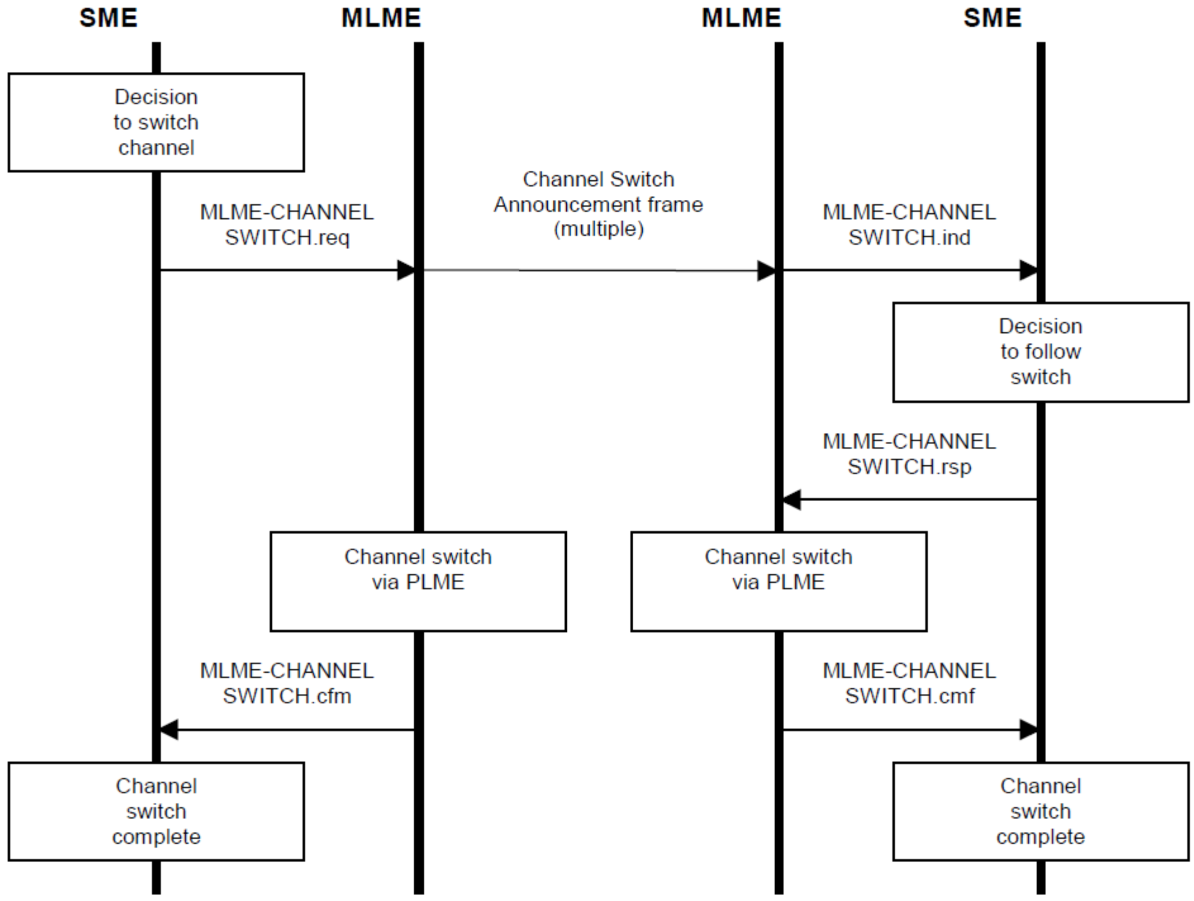
Frequency band (GHz)	**United States (Maximum output power with up to 6 dBi antenna gain) (mW)**	**Europe (EIRP)**
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	**U.S. public safety (mW)**		
	20 MHz channels	**10 MHz channels**	**5 MHz channels**
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

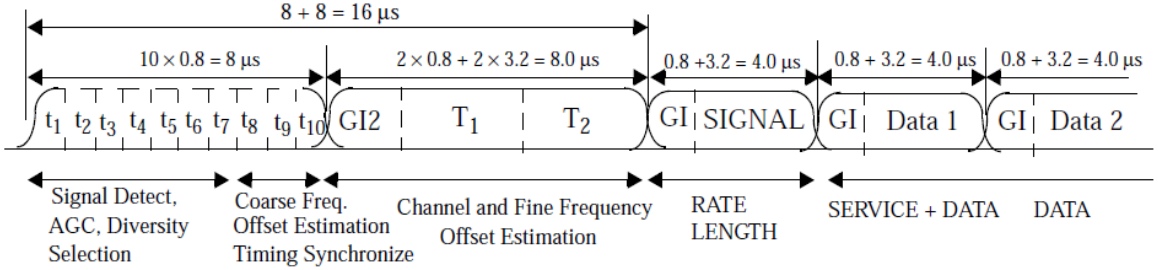
Claim 9 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

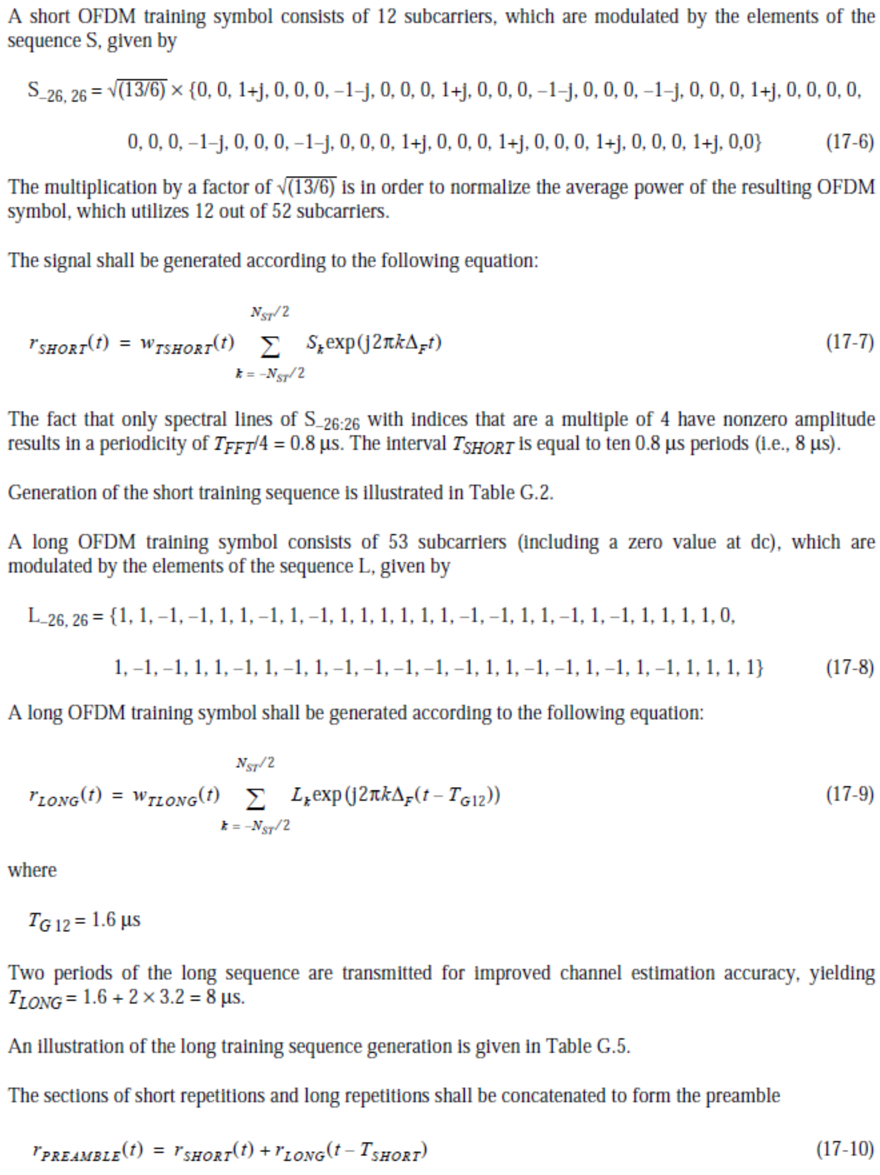
Claim 9 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 9 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
[10.1] A method of transmitting information in a wireless communication channel comprising:	To the extent the preamble is limiting, 802.11-2007 discloses “A method of transmitting information in a wireless communication channel comprising.” See, e.g.:

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.2] receiving a first digital signal comprising first data to be transmitted;	802.11-2007 discloses "receiving a first digital signal comprising first data to be transmitted." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks

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	this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC**

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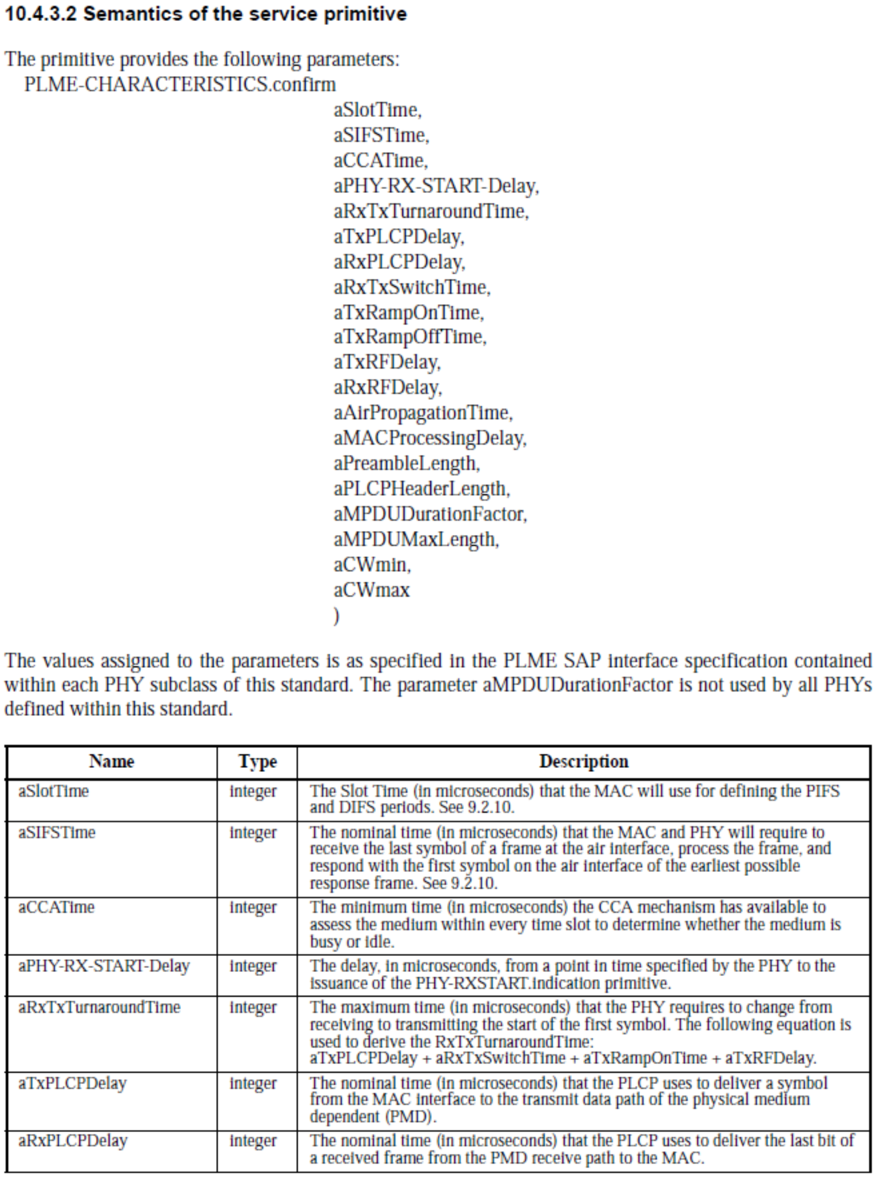
	Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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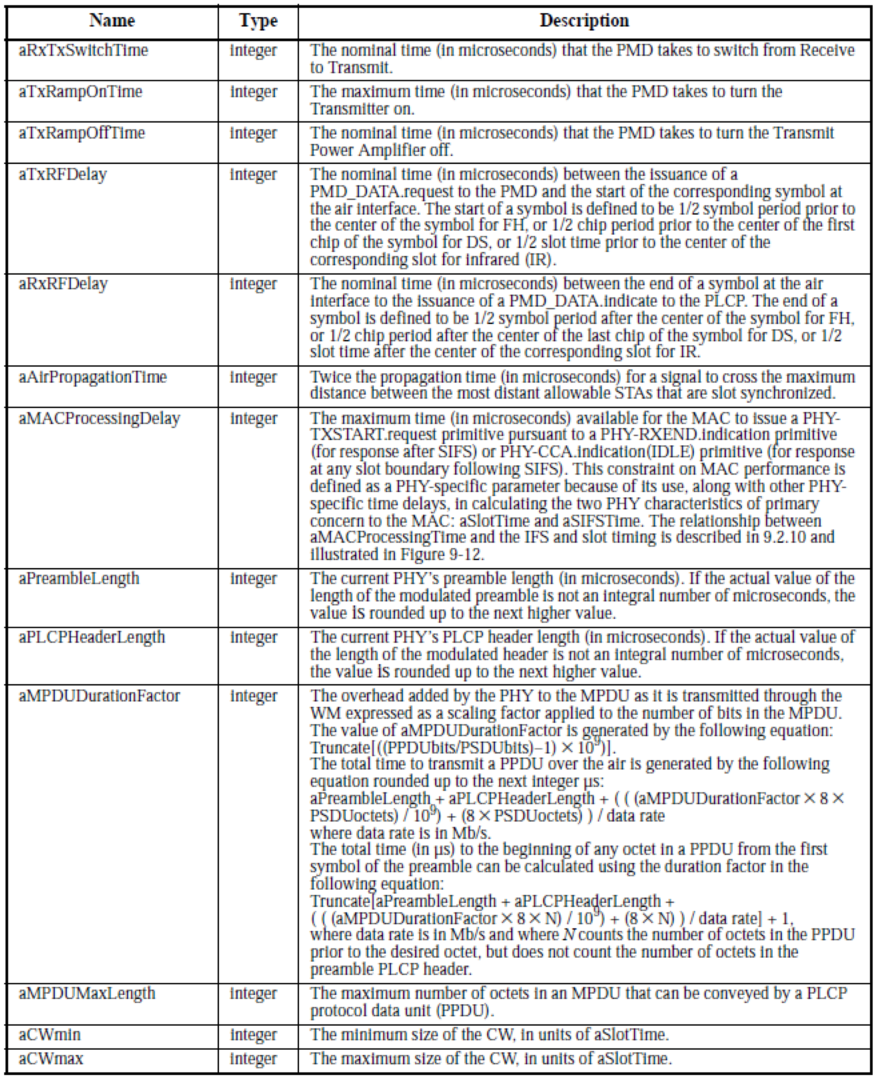

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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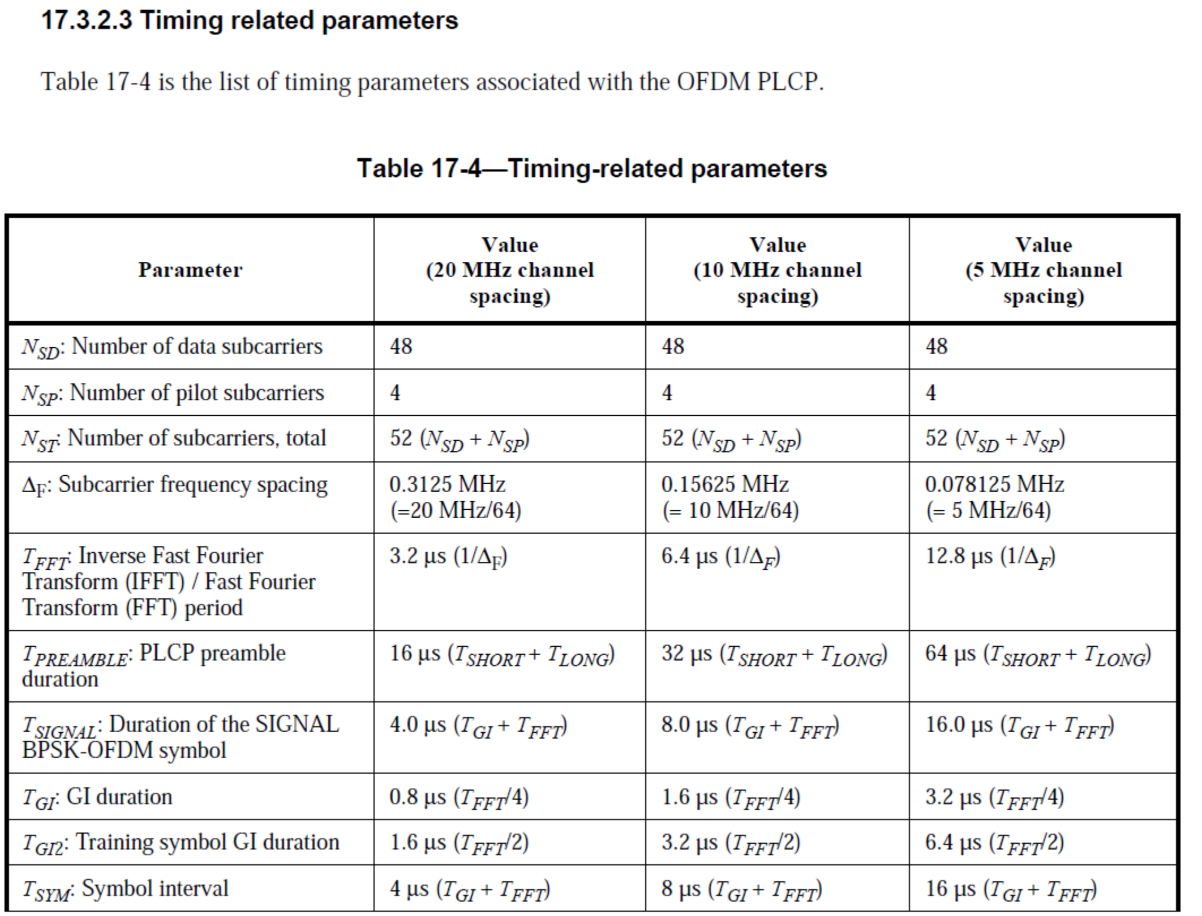

17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

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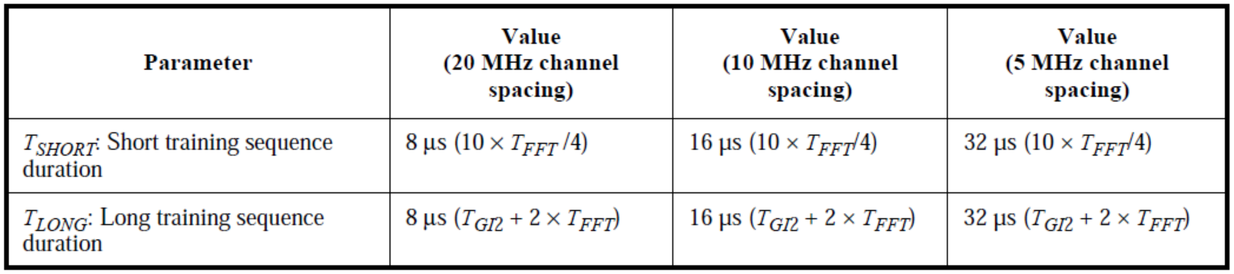

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
T_{SHORT}: Short training sequence duration	8 µs (10 × T_{FFT} /4)	16 µs (10 × T_{FFT}/4)	32 µs (10 × T_{FFT}/4)
T_{LONG}: Long training sequence duration	8 µs (T_{GI2} + 2 × T_{FFT})	16 µs (T_{GI2} + 2 × T_{FFT})	32 µs (T_{GI2} + 2 × T_{FFT})

See, e.g., 802.11-2007 § 17.3.2.3

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	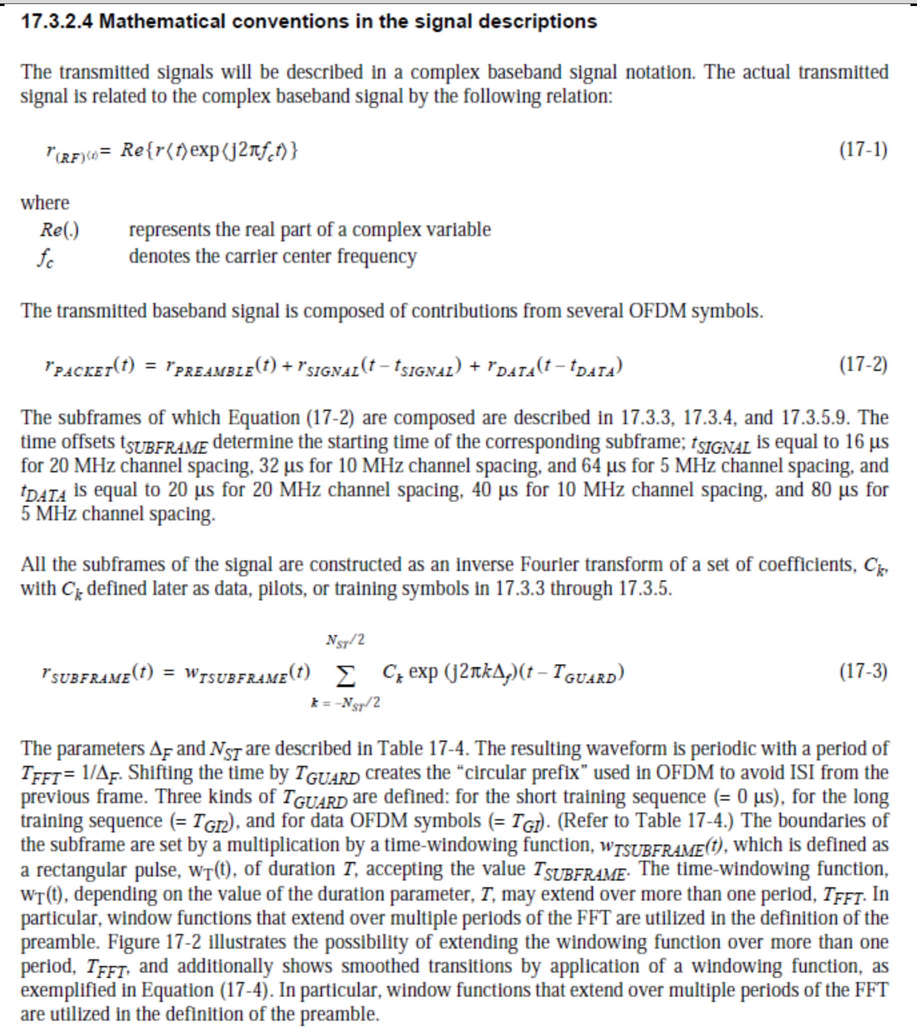 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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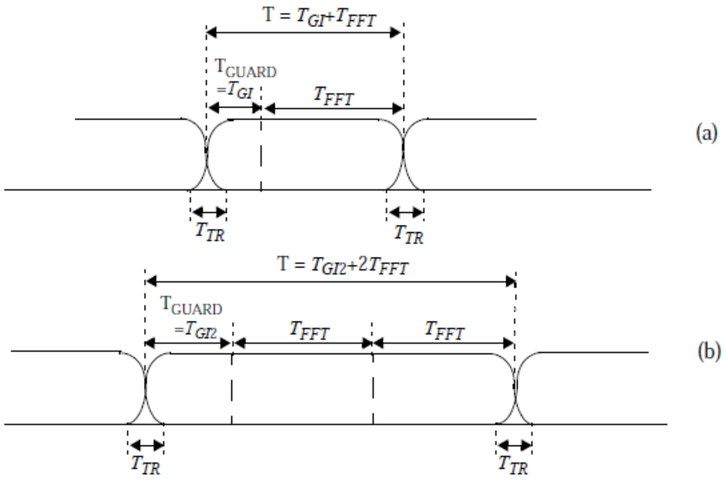
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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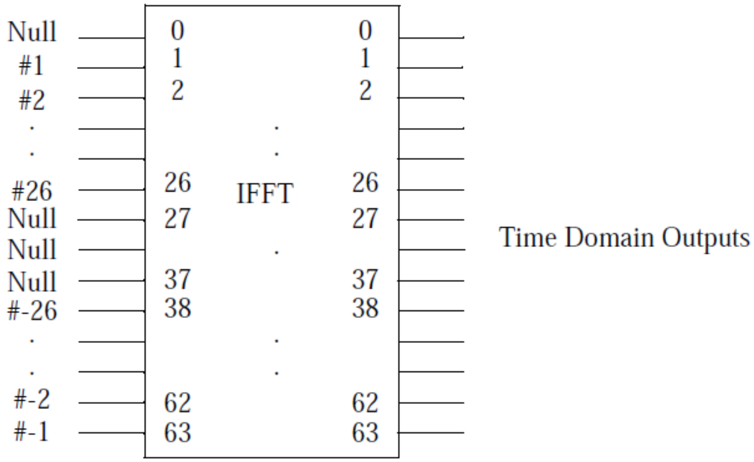
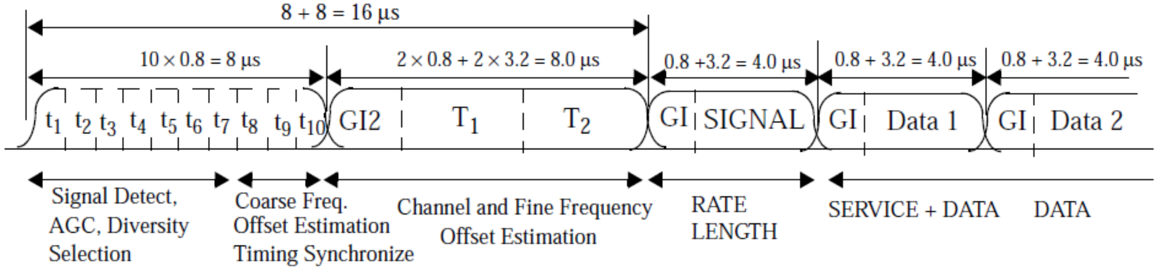
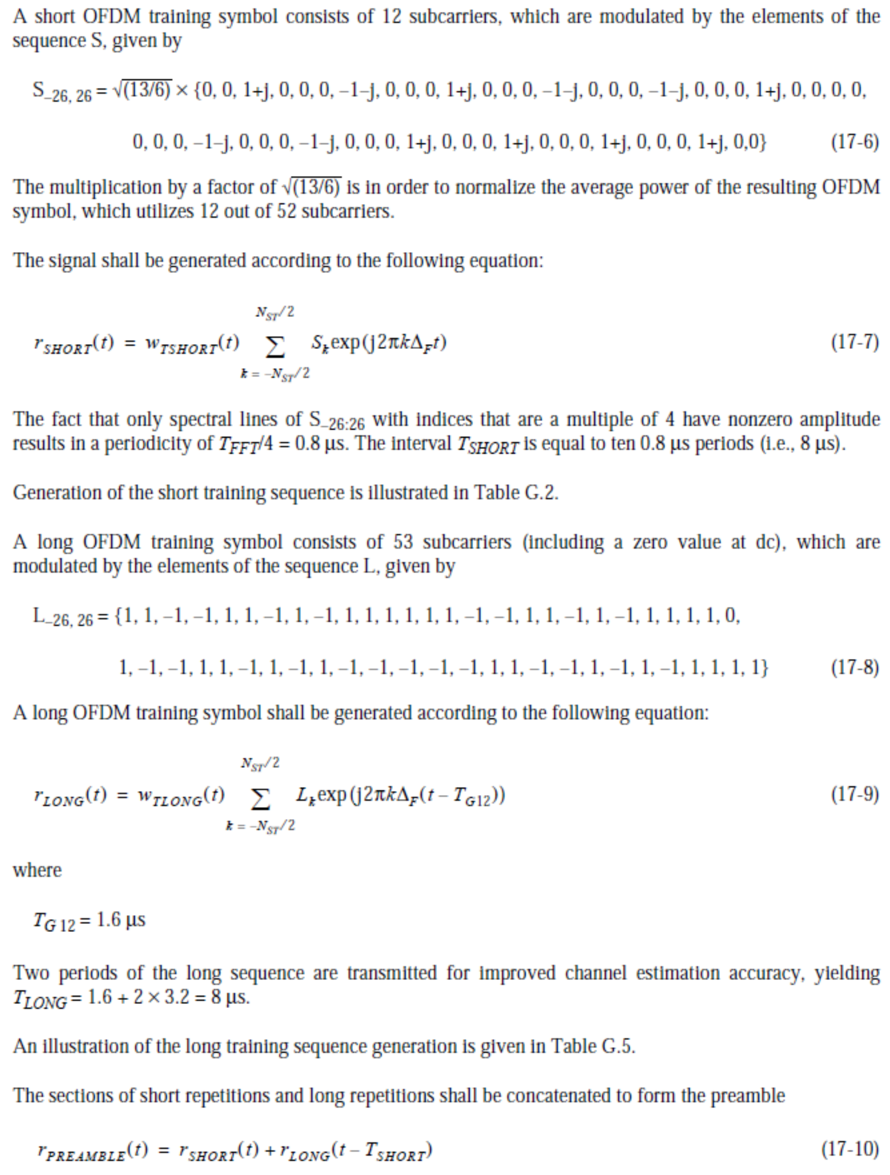
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \left\{\begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array}\right\} \qquad (17\text{-}5)$ The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

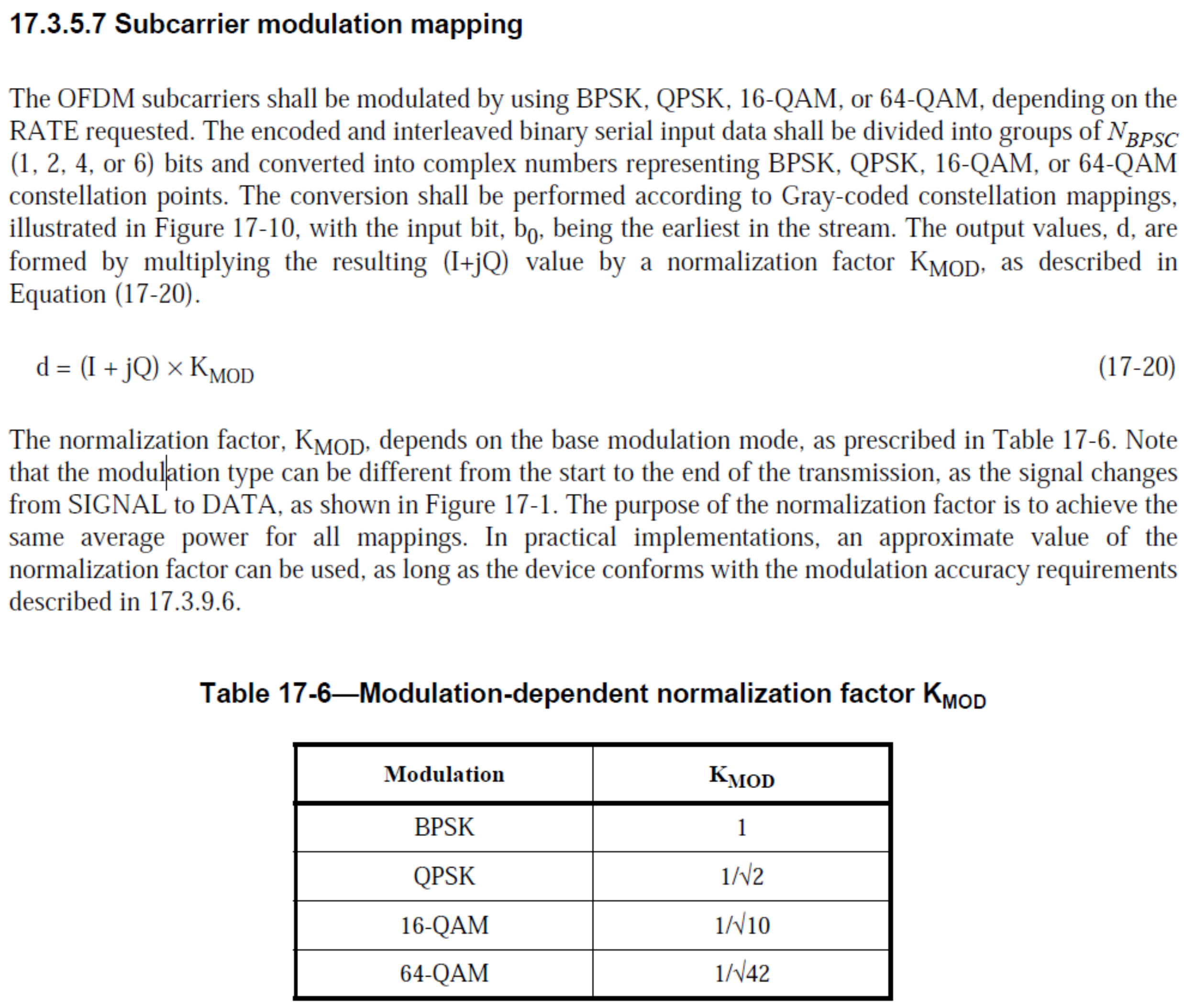
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

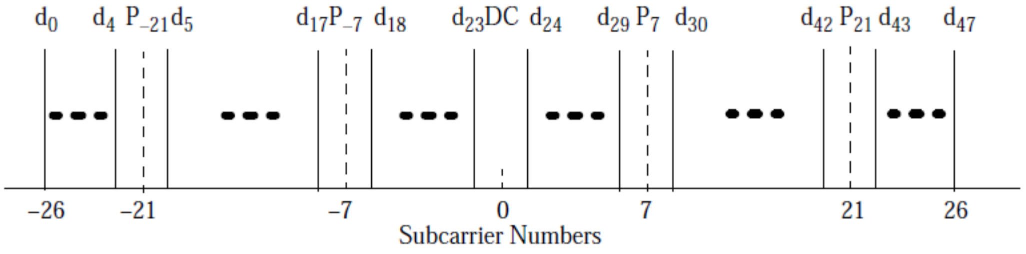


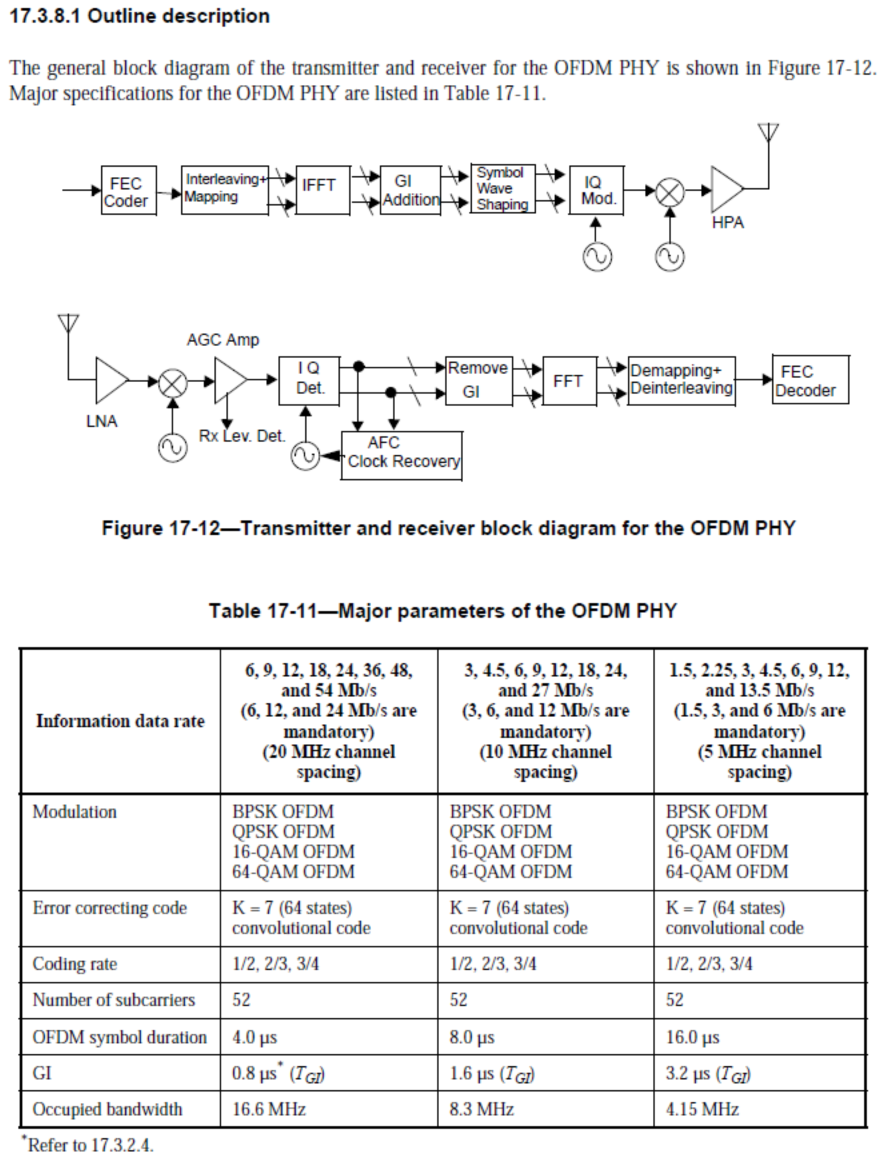
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

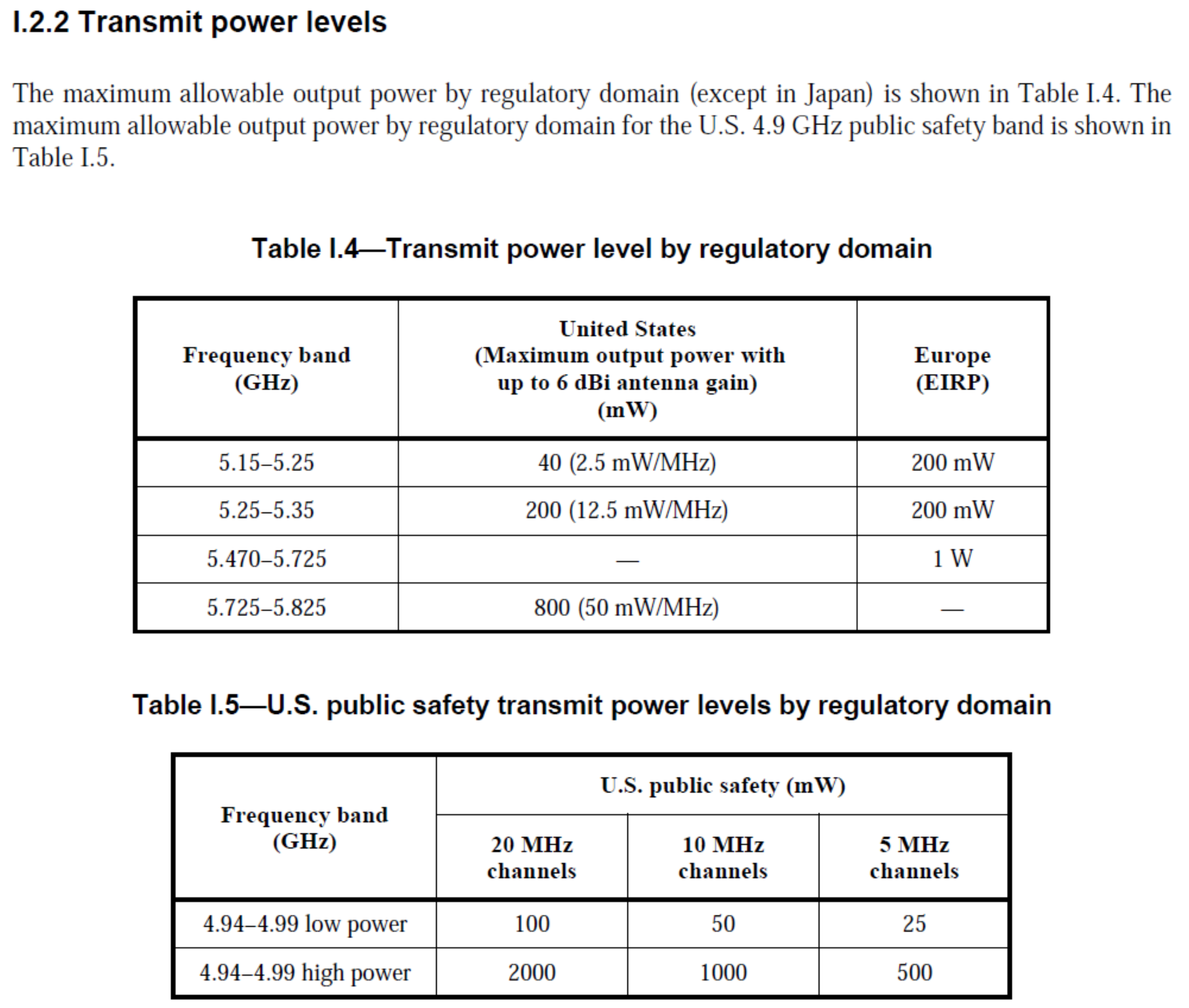
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

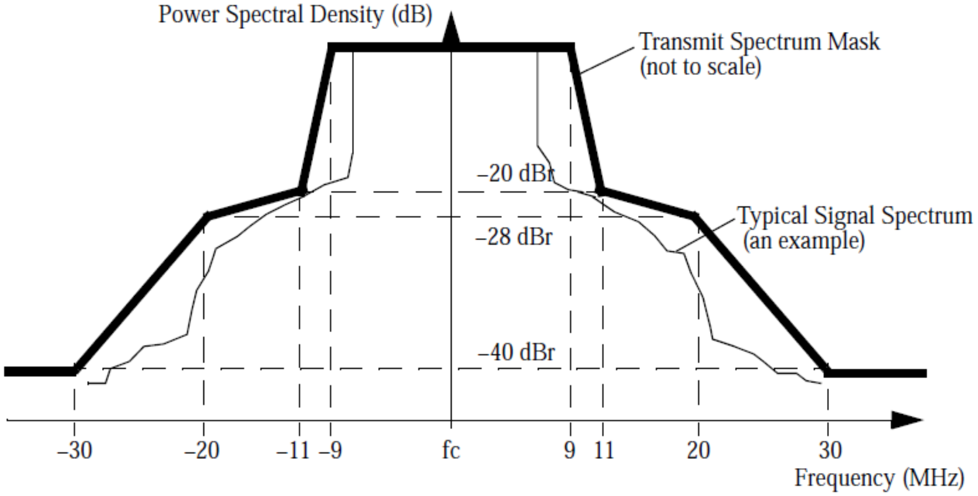
Table I.4—Transmit power level by regulatory domain

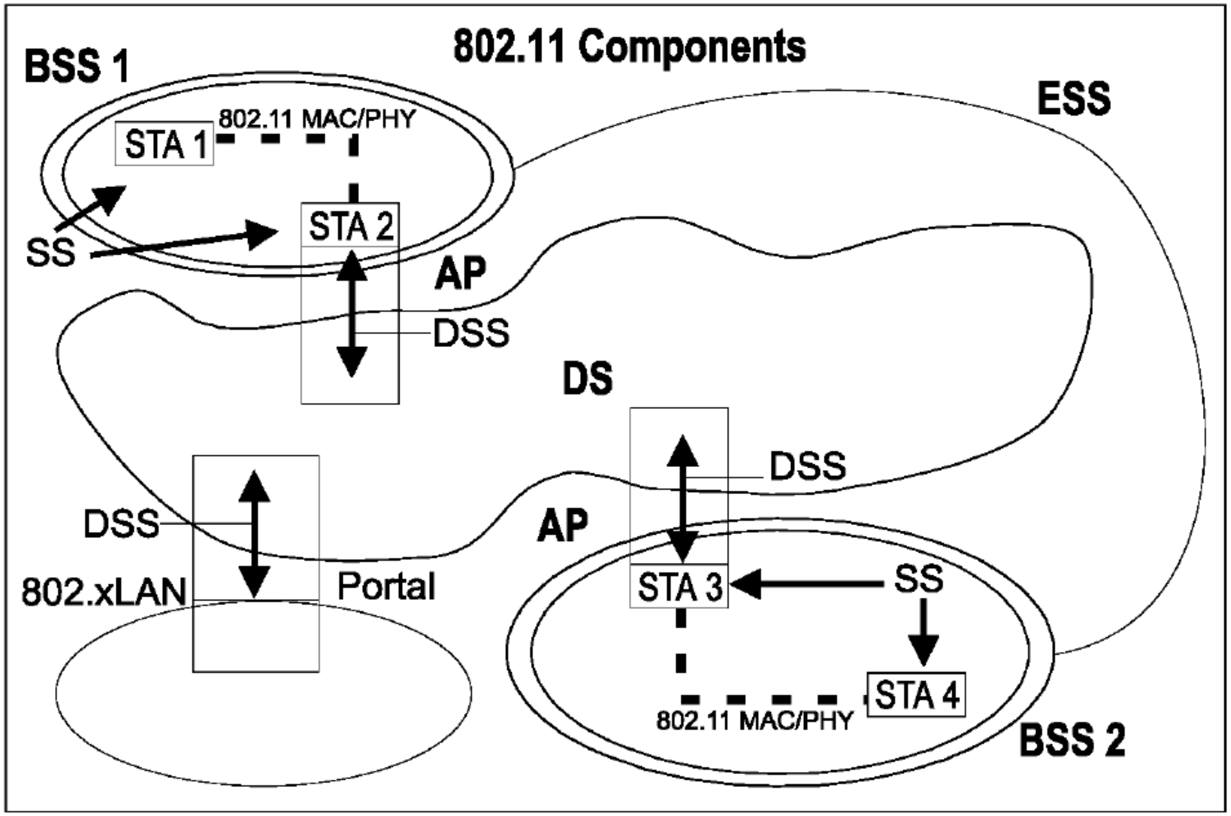
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

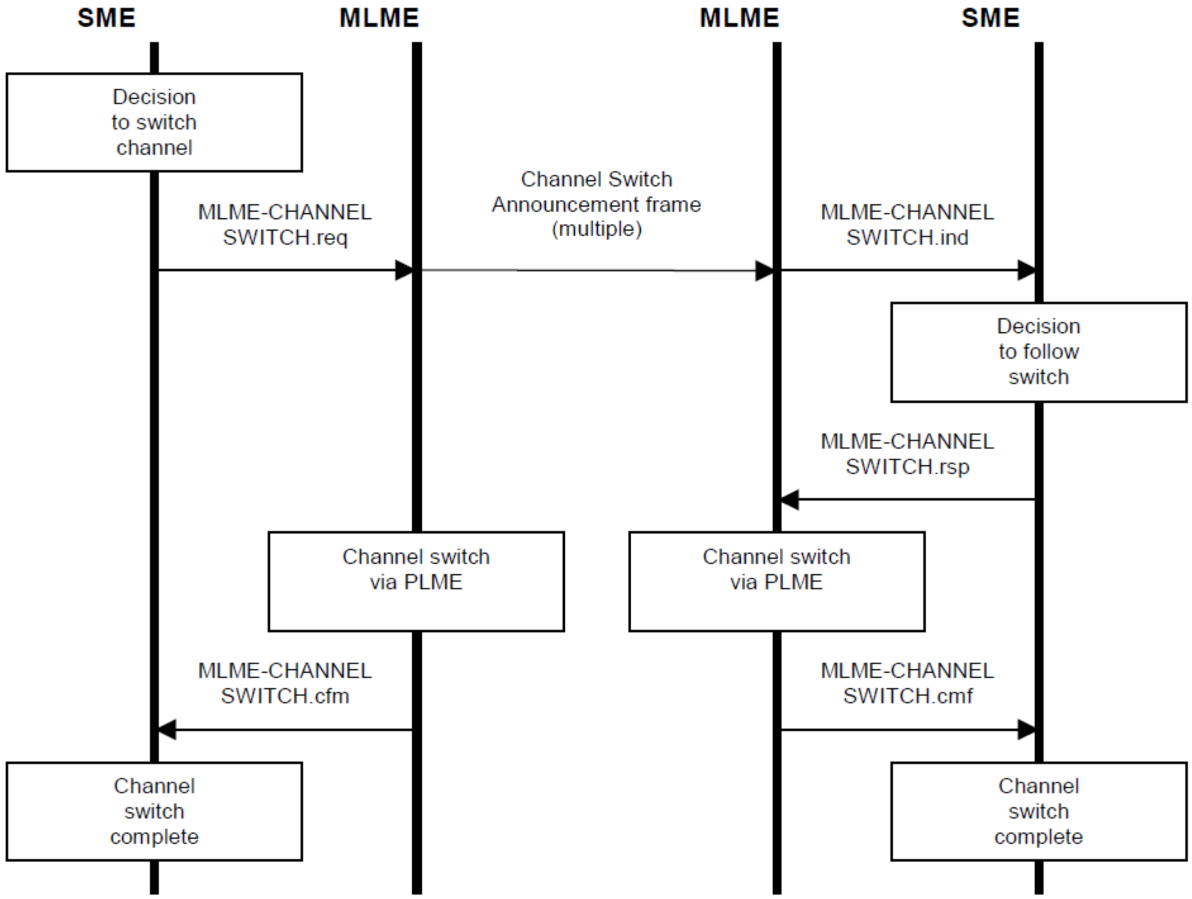
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

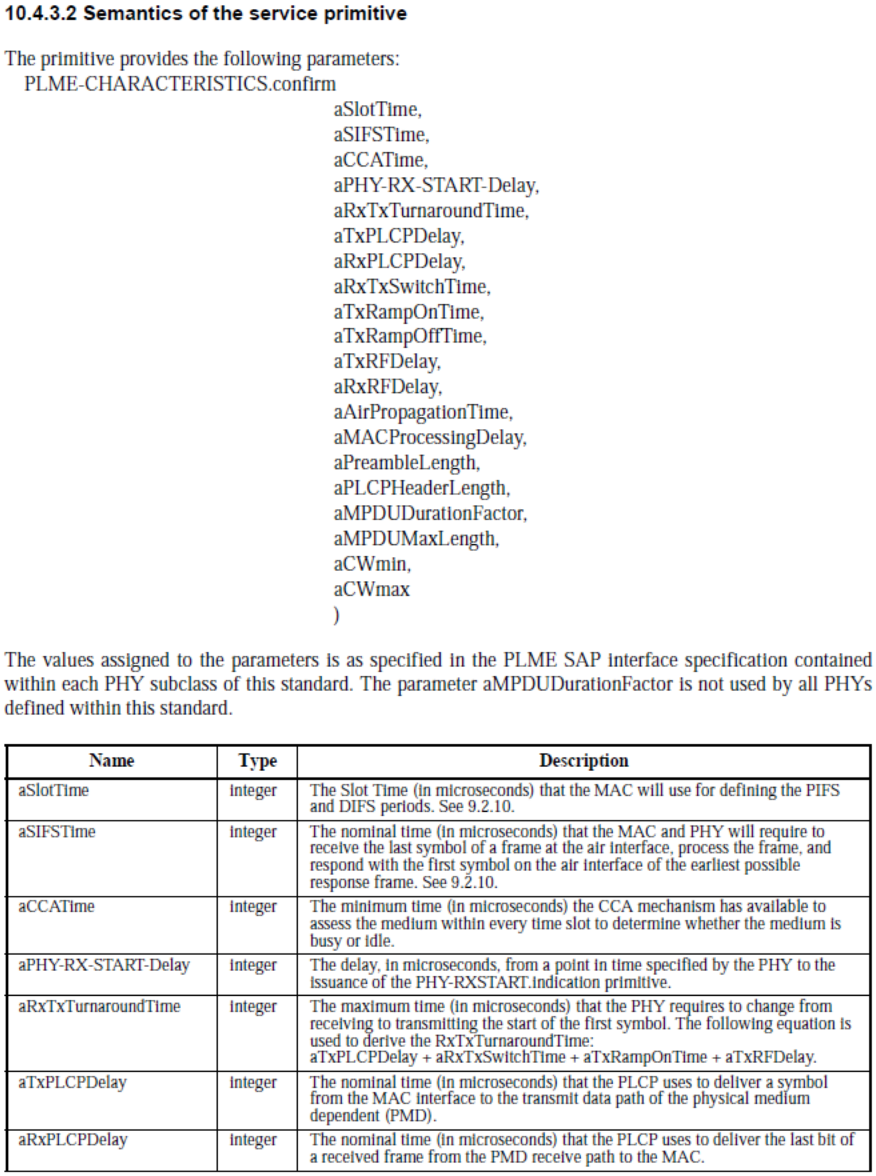
Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.3] receiving a second digital signal comprising second data to be transmitted;	802.11-2007 discloses “receiving a second digital signal comprising second data to be transmitted.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

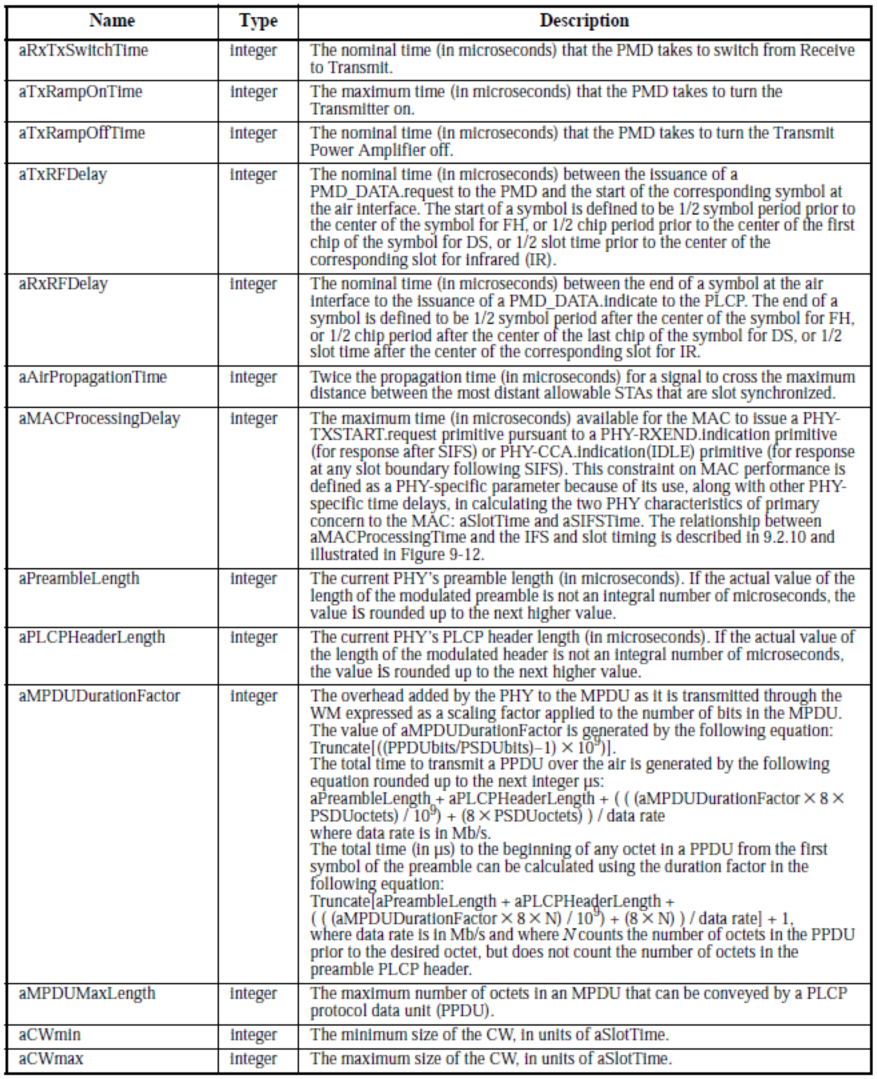
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007

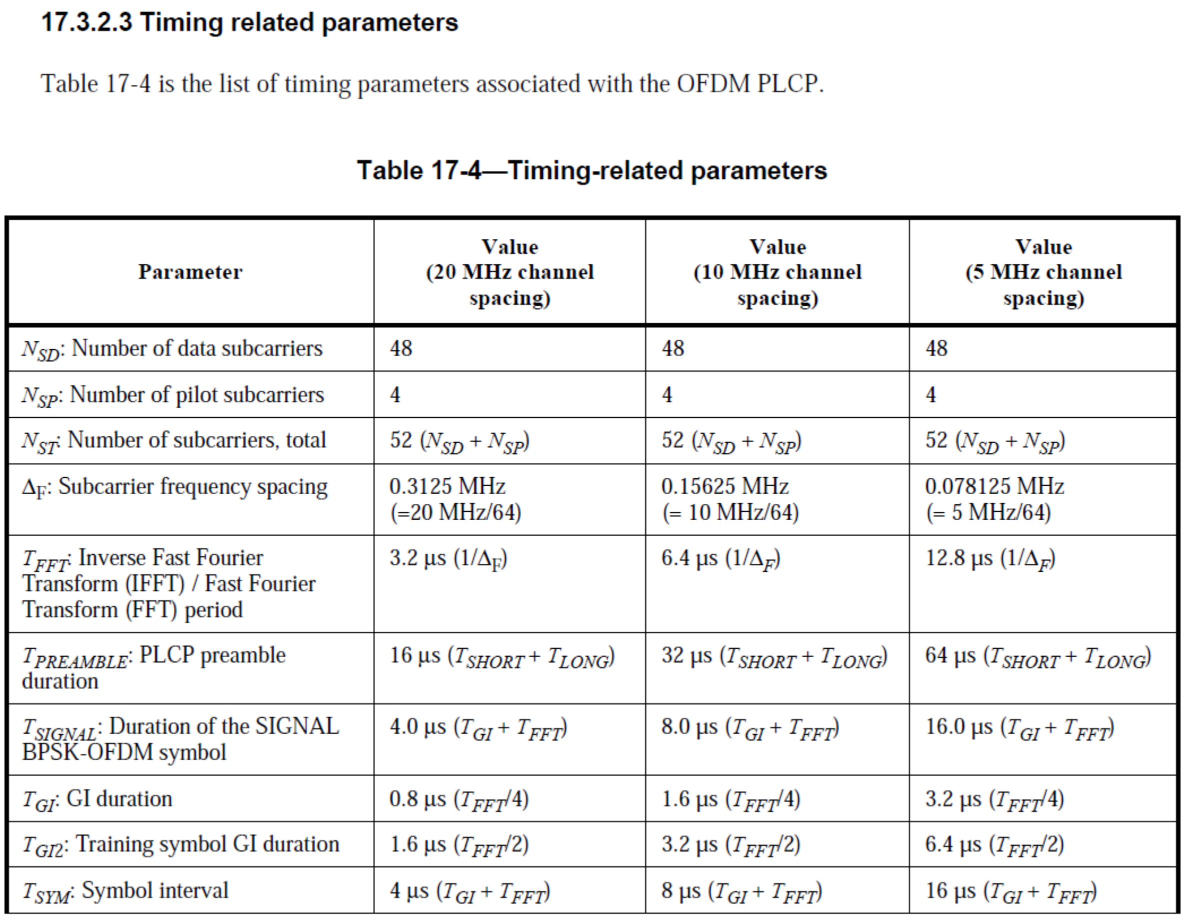


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

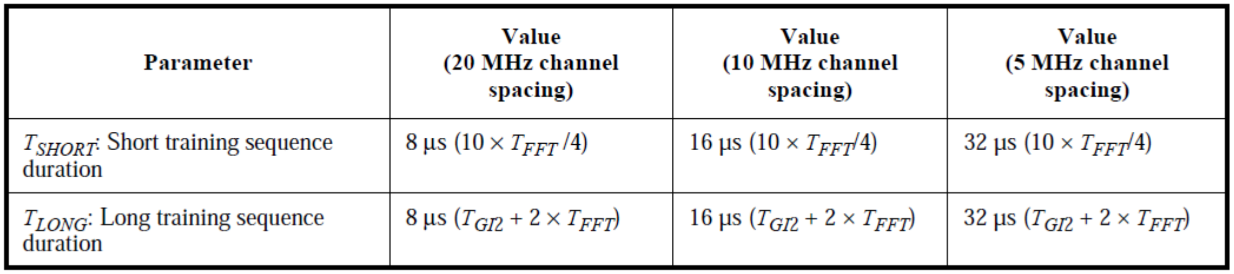
Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

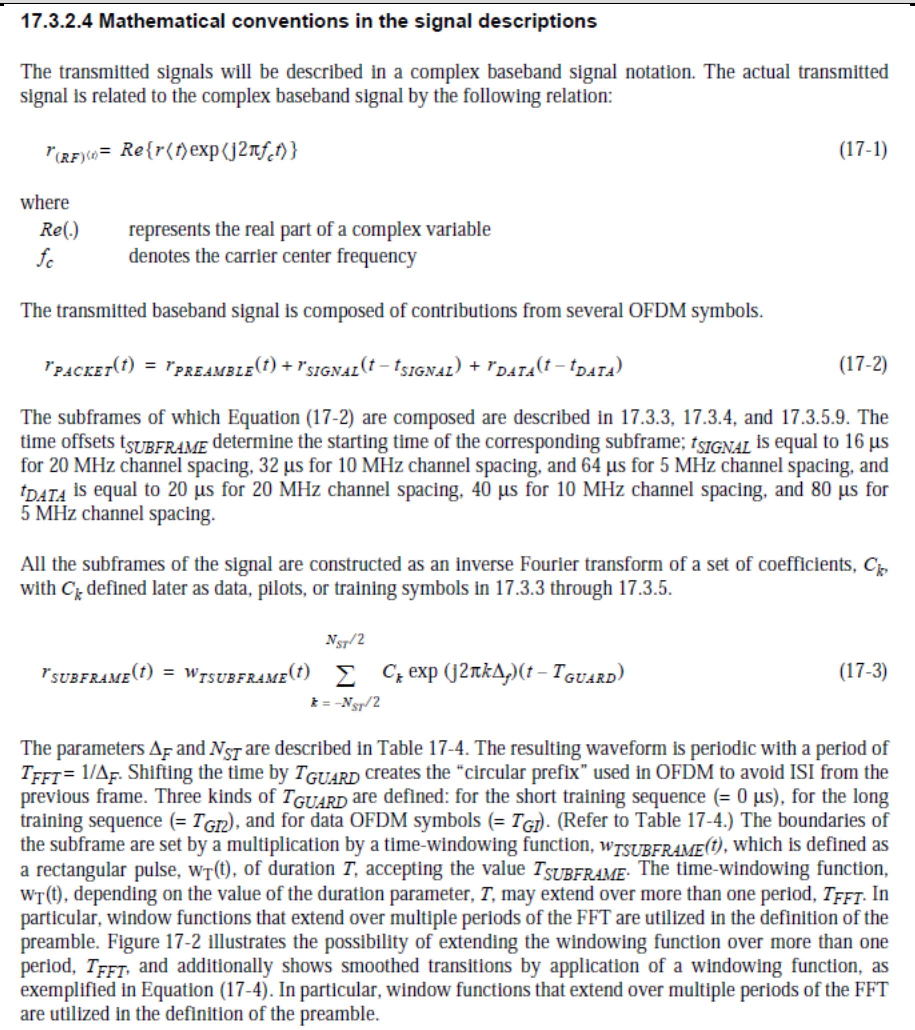
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

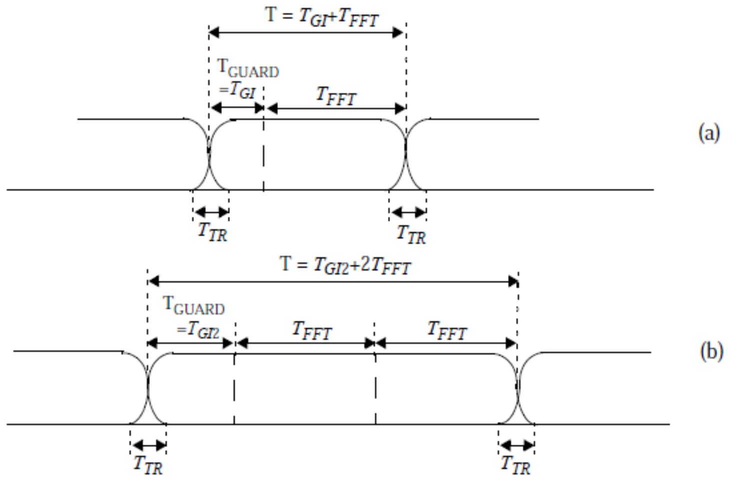
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

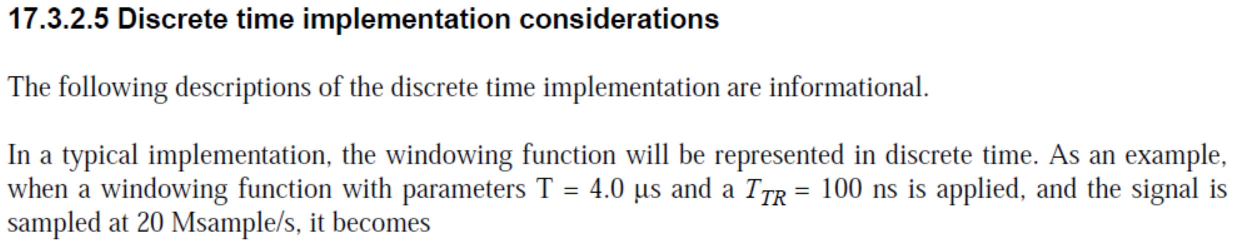
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

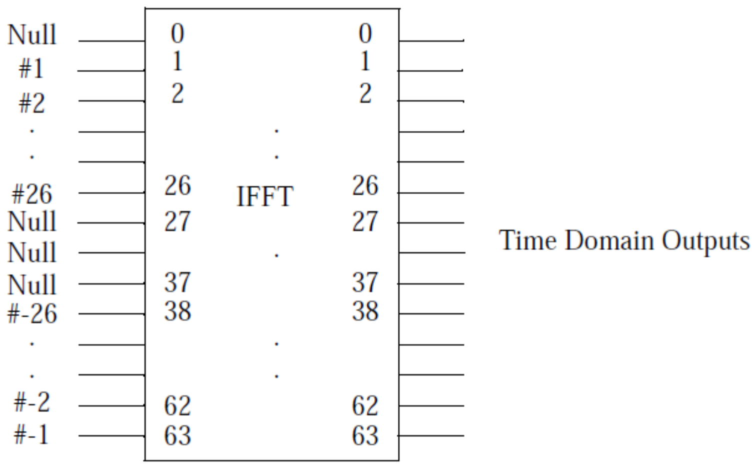
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

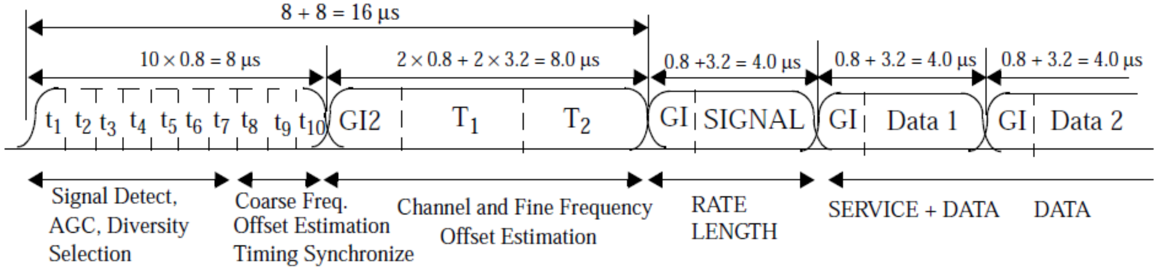
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

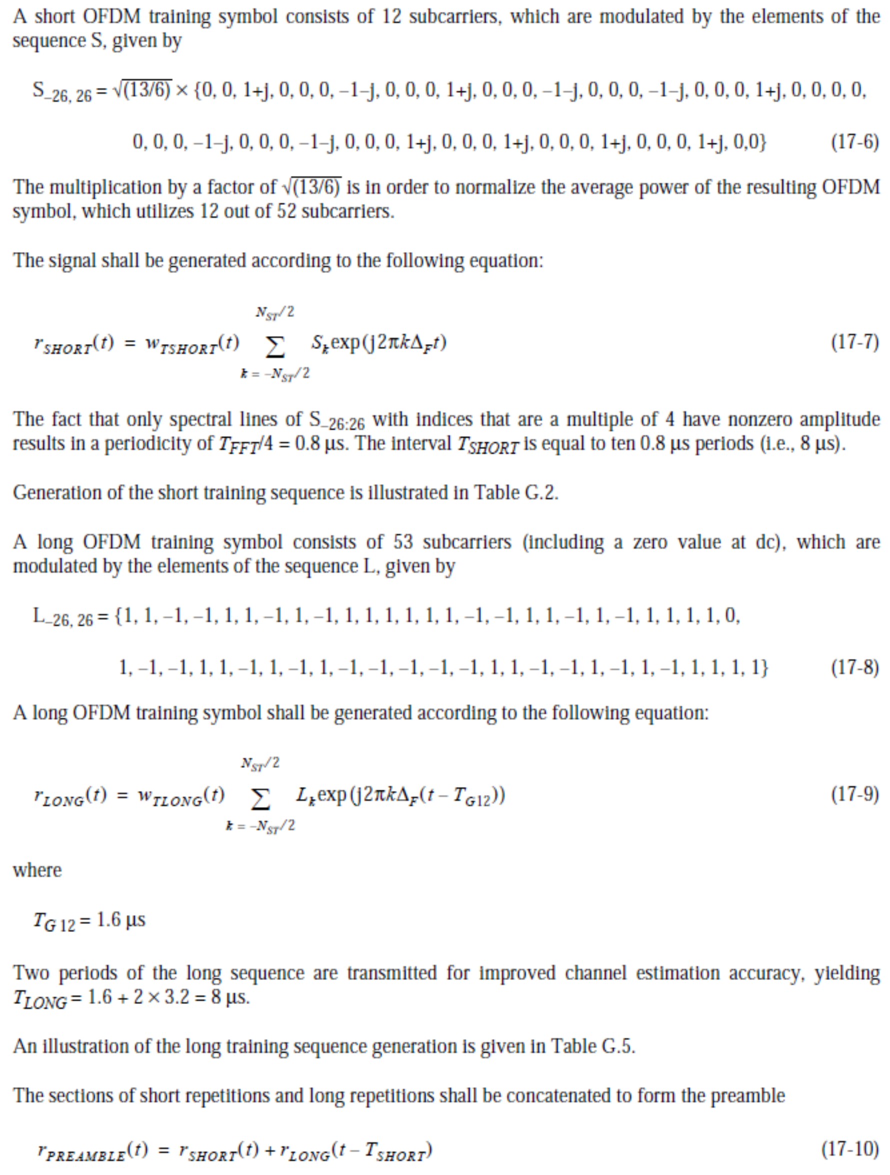
The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

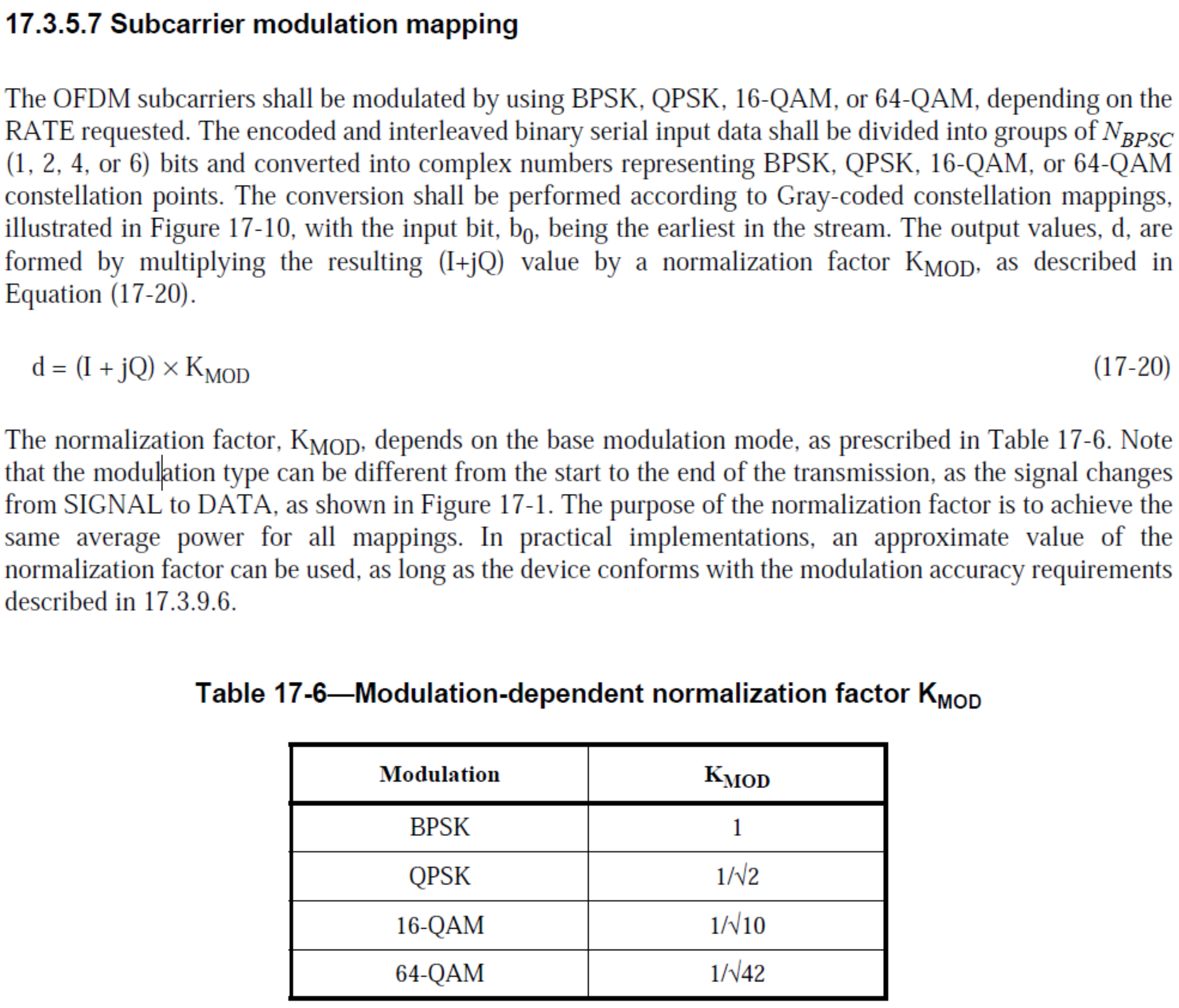
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the nth OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

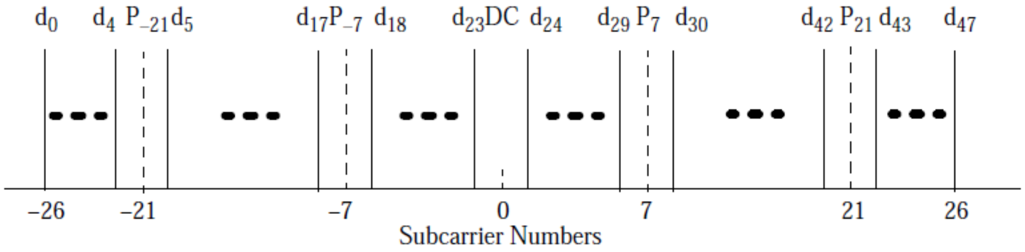


Figure 17-11—Subcarrier frequency allocation

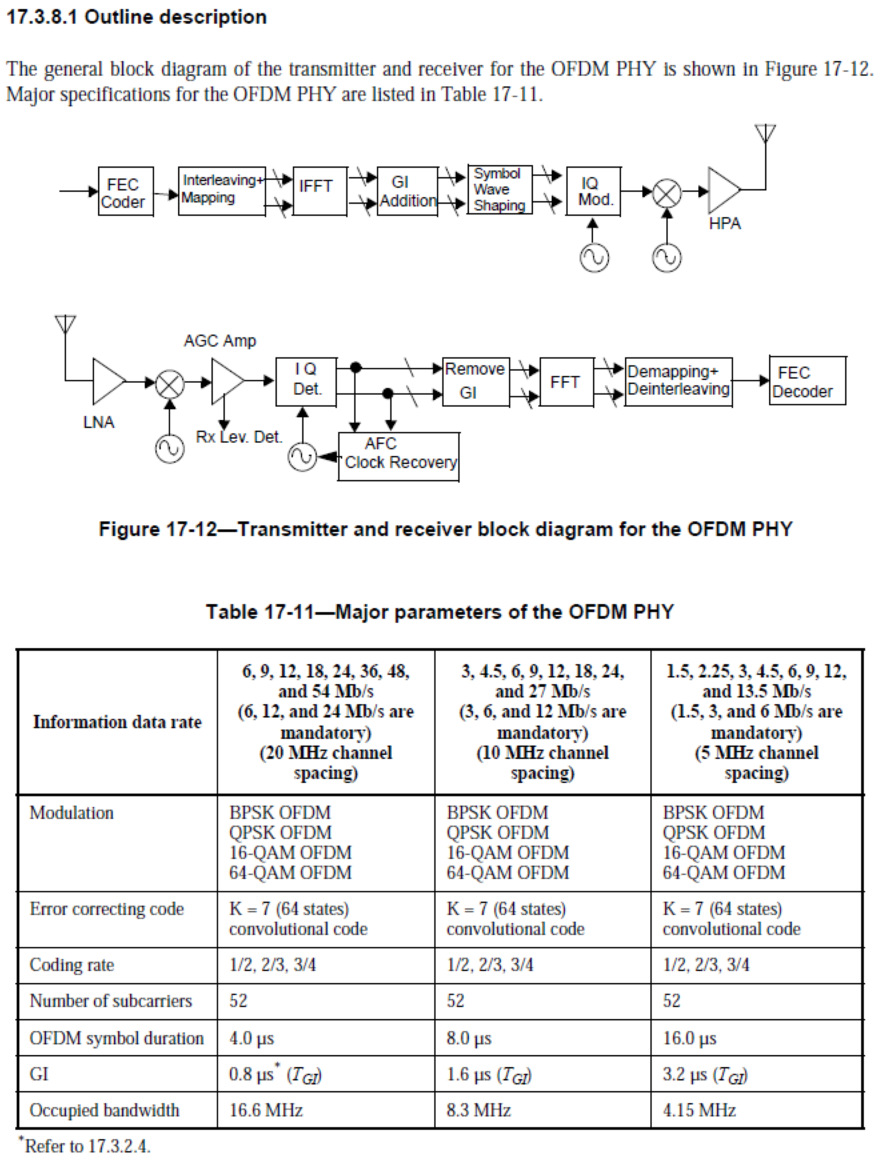
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

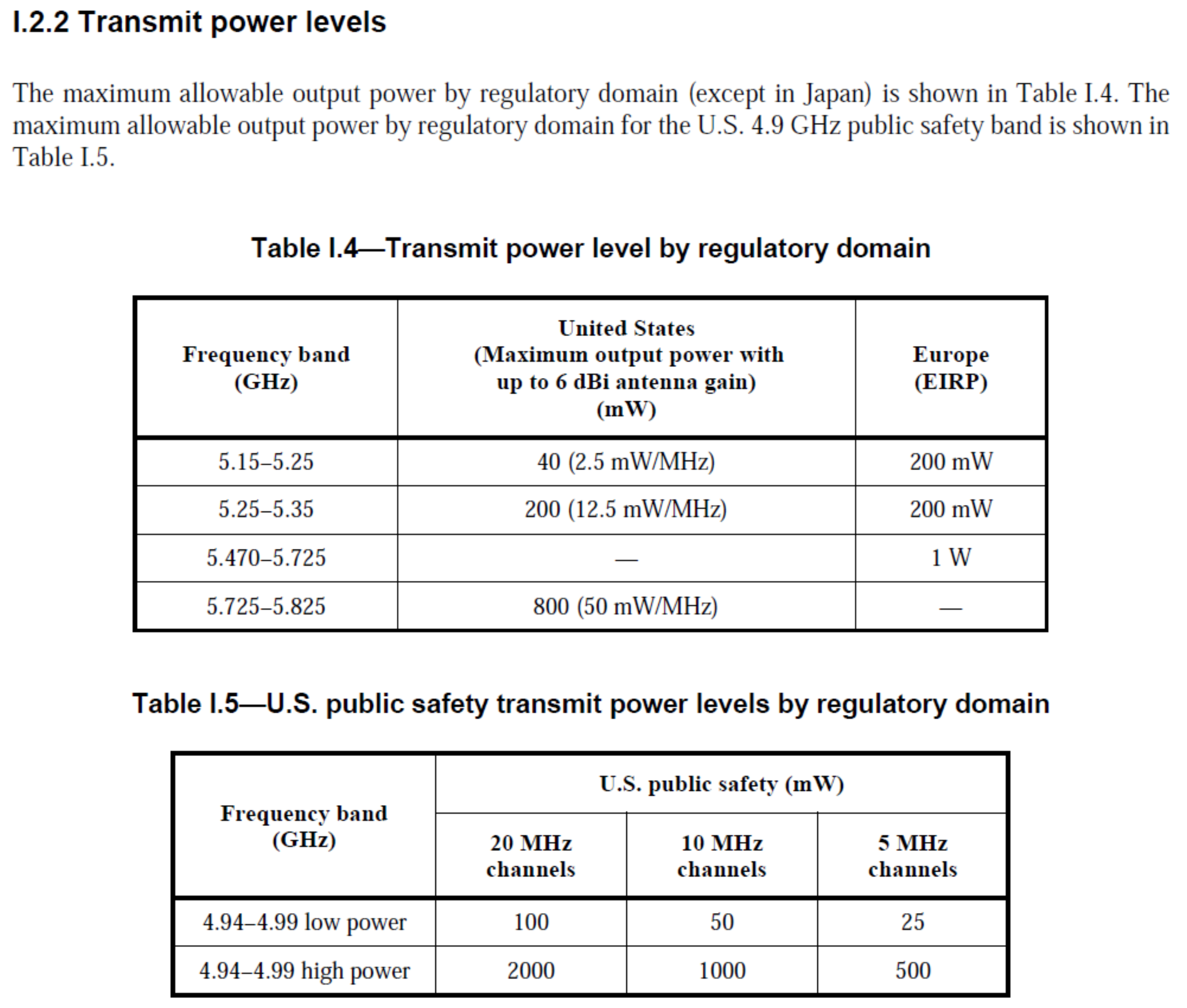
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

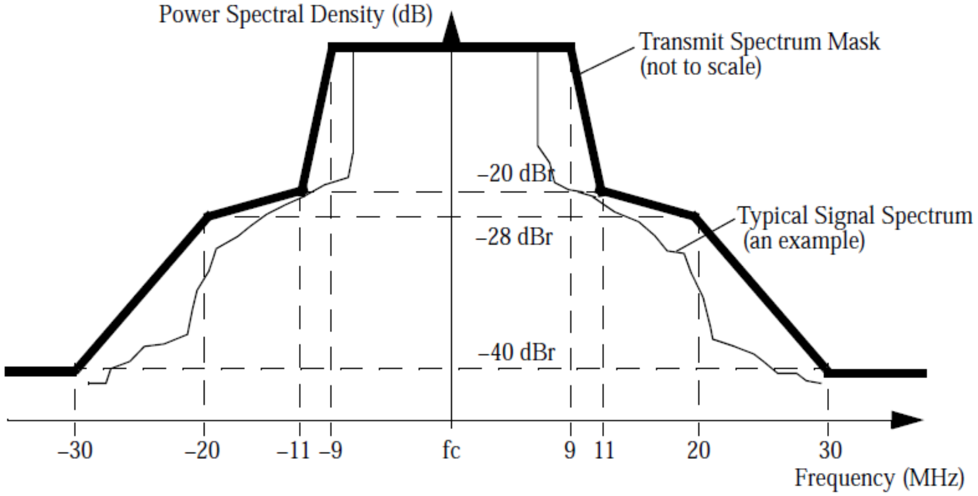
Table I.4—Transmit power level by regulatory domain

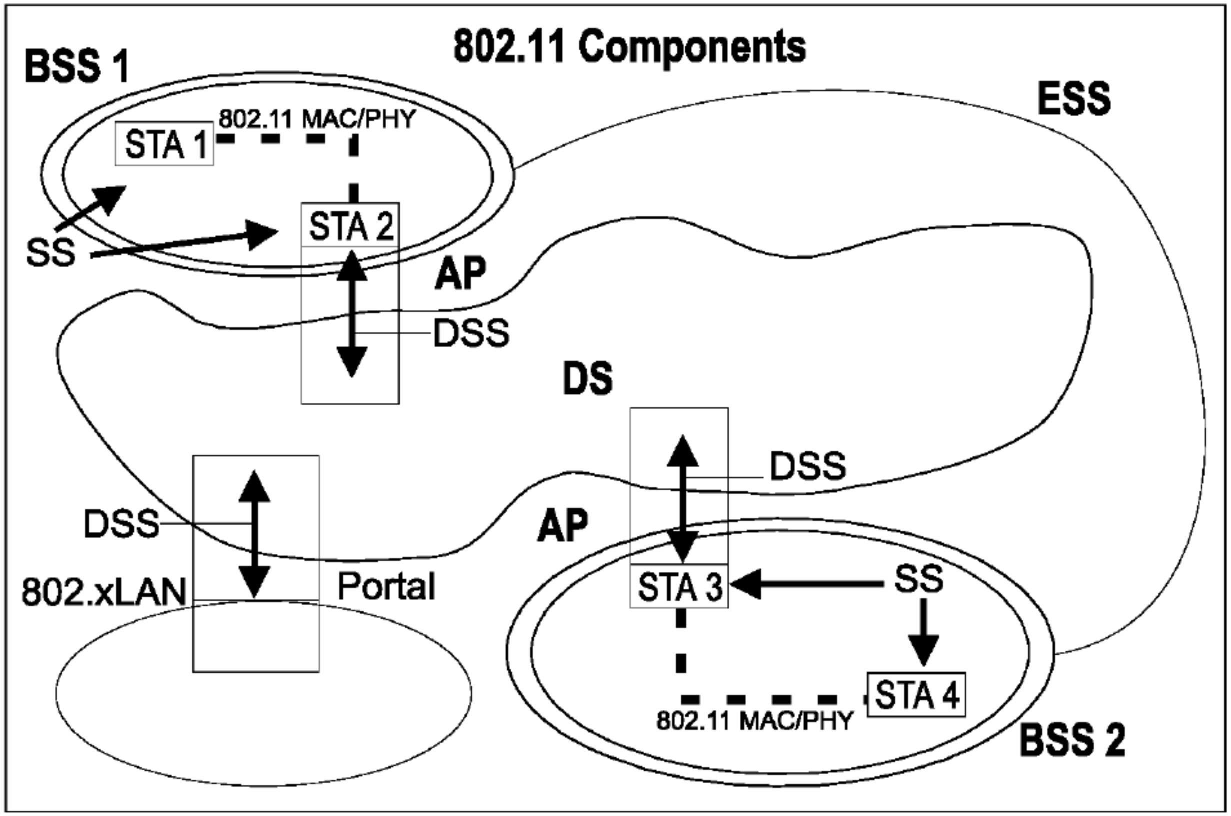
Frequency band (GHz)	**United States (Maximum output power with up to 6 dBi antenna gain) (mW)**	**Europe (EIRP)**
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

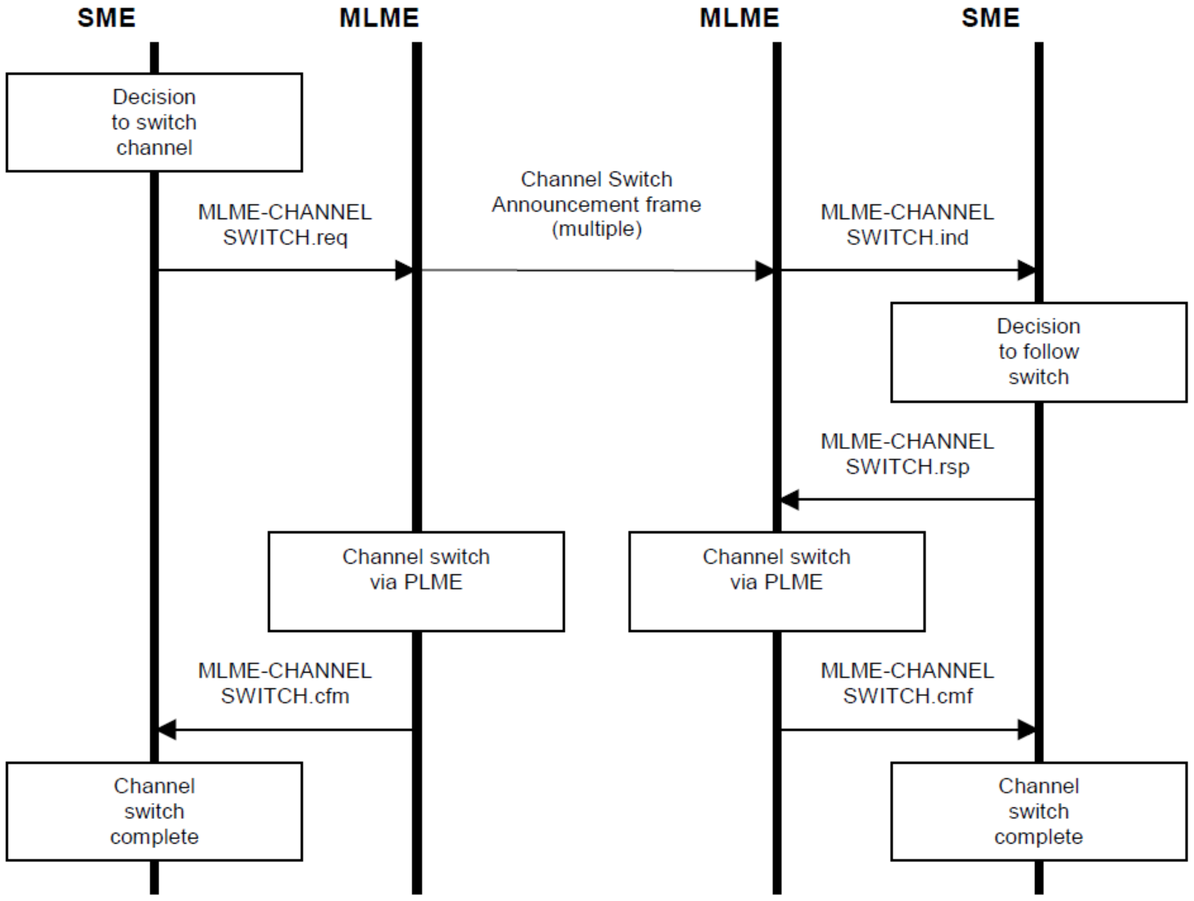
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	**U.S. public safety (mW)**		
	20 MHz channels	**10 MHz channels**	**5 MHz channels**
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

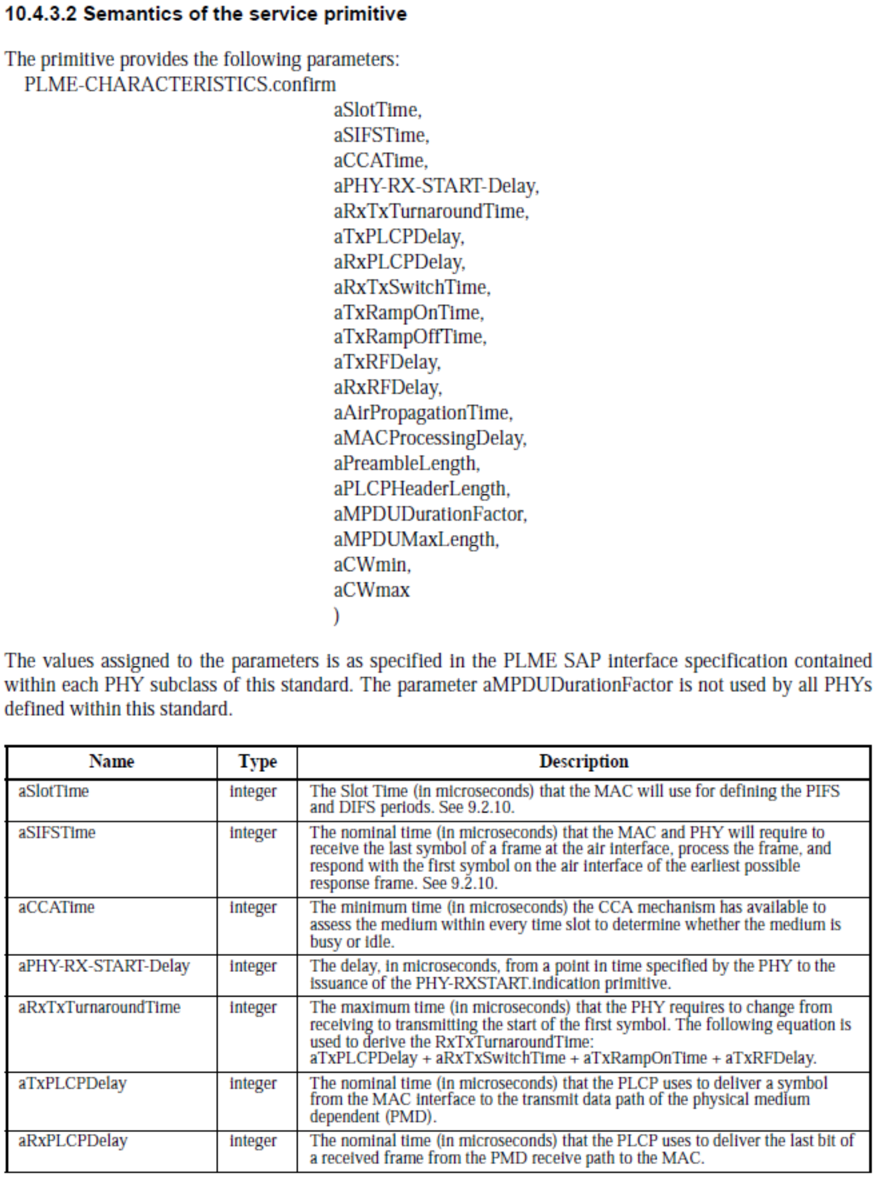
Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.4] converting the first digital signal into a first analog signal using a first digital-to-analog converter, the first analog signal carrying the first data across a first frequency range;.	802.11-2007 discloses “converting the first digital signal into a first analog signal using a first digital-to-analog converter, the first analog signal carrying the first data across a first frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

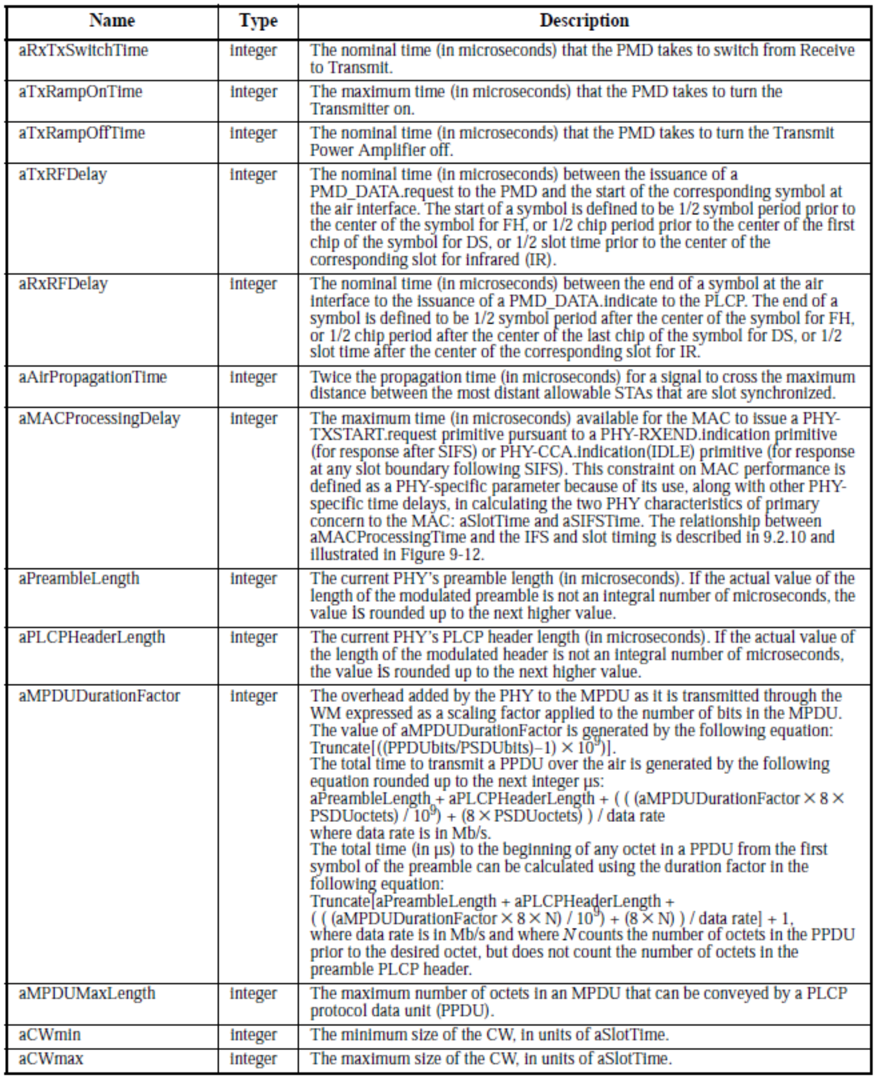
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007

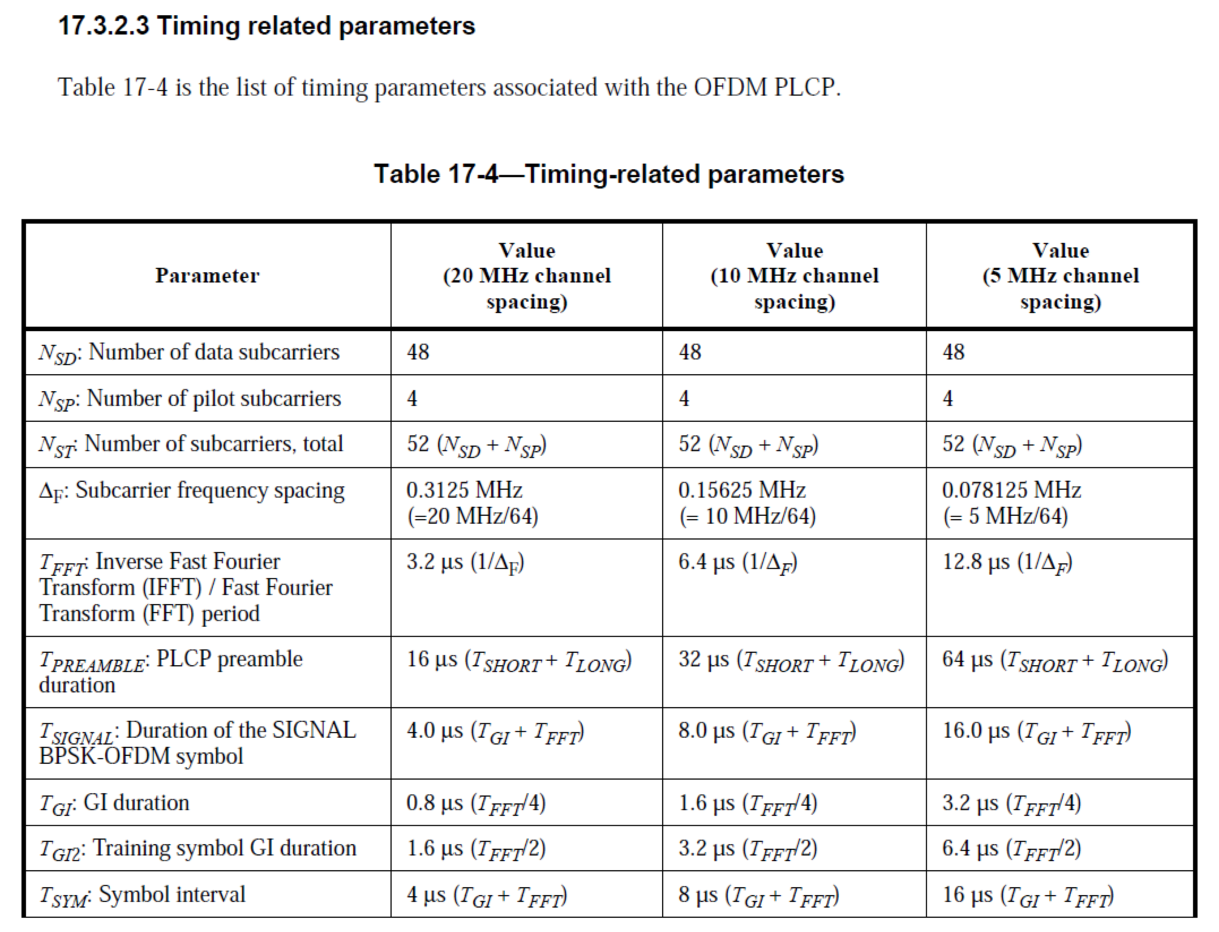


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz (=20 MHz/64)</td><td>0.15625 MHz (= 10 MHz/64)</td><td>0.078125 MHz (= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 μs ($1/\Delta_F$)</td><td>6.4 μs ($1/\Delta_F$)</td><td>12.8 μs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 μs ($T_{SHORT} + T_{LONG}$)</td><td>32 μs ($T_{SHORT} + T_{LONG}$)</td><td>64 μs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 μs ($T_{GI} + T_{FFT}$)</td><td>8.0 μs ($T_{GI} + T_{FFT}$)</td><td>16.0 μs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 μs ($T_{FFT}/4$)</td><td>1.6 μs ($T_{FFT}/4$)</td><td>3.2 μs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 μs ($T_{FFT}/2$)</td><td>3.2 μs ($T_{FFT}/2$)</td><td>6.4 μs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 μs ($T_{GI} + T_{FFT}$)</td><td>8 μs ($T_{GI} + T_{FFT}$)</td><td>16 μs ($T_{GI} + T_{FFT}$)</td></tr>
</table>
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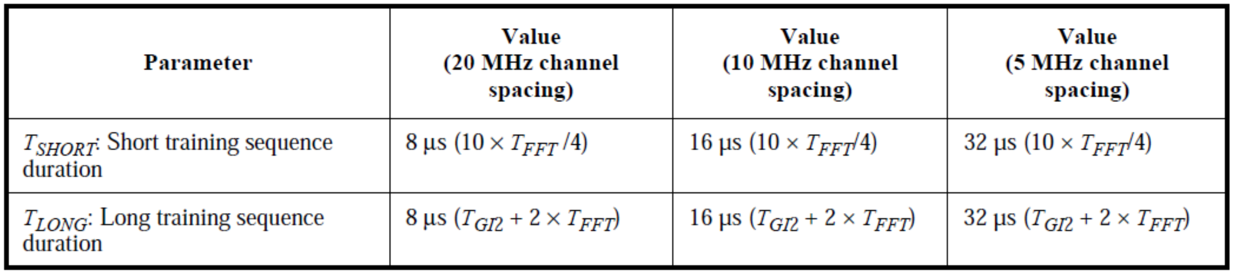
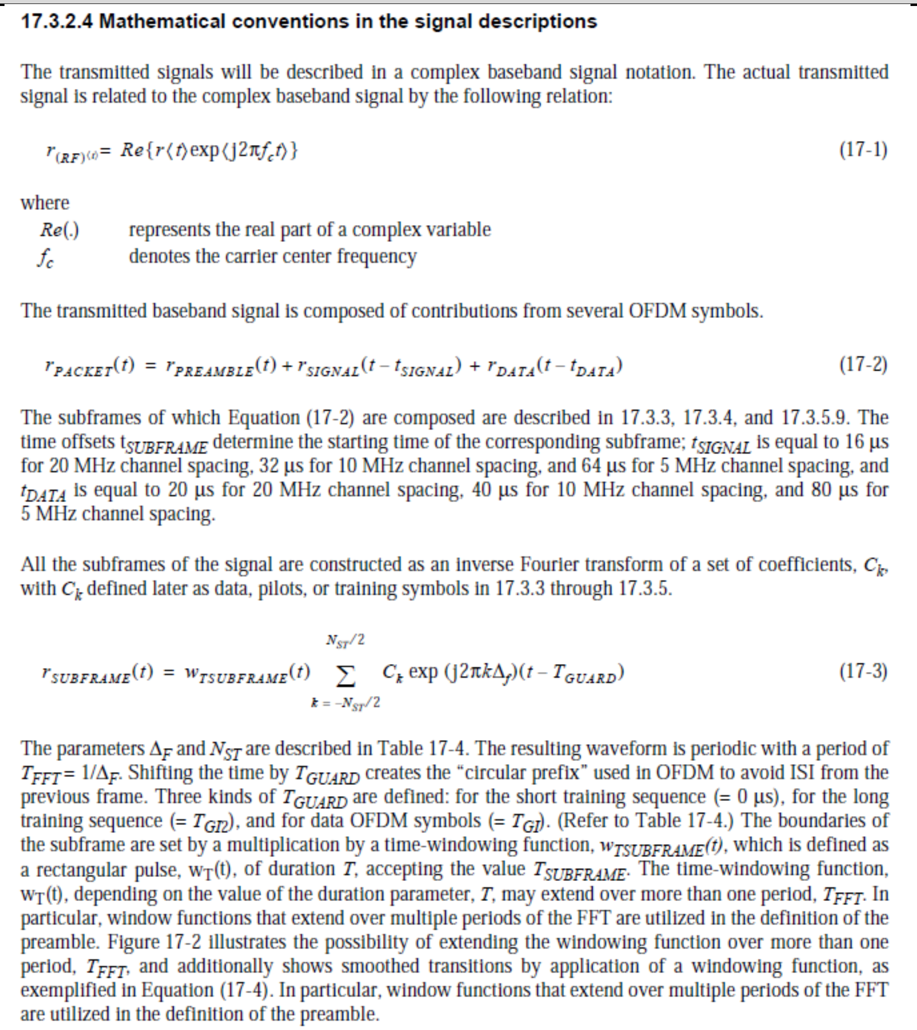
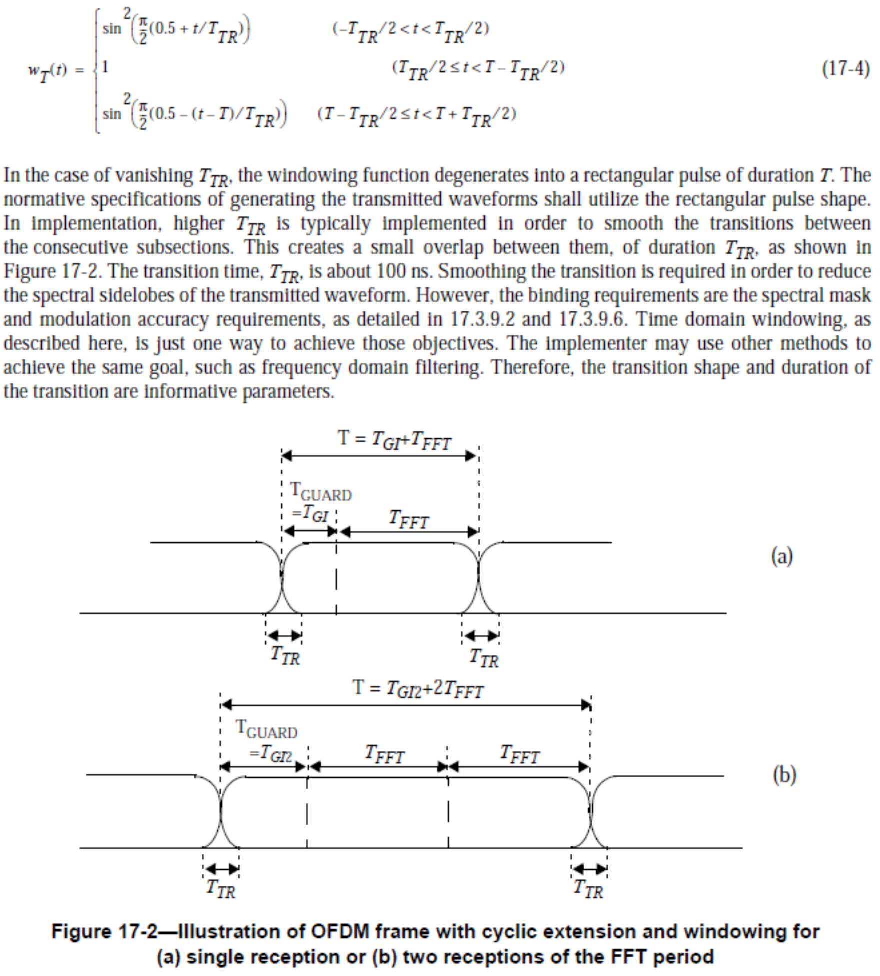
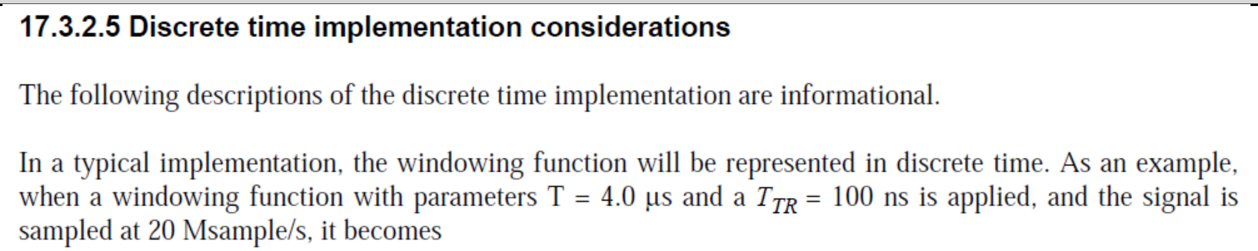
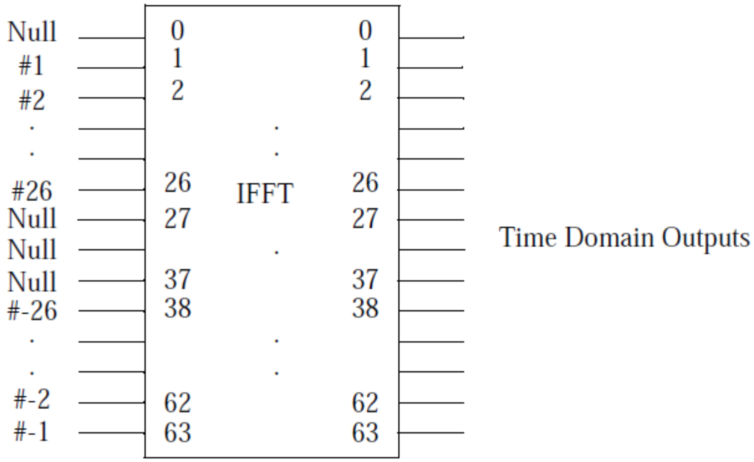
<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>
<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 μs (10 × T_{FFT} /4)</td><td>16 μs (10 × T_{FFT}/4)</td><td>32 μs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 μs (T_{GI2} + 2 × T_{FFT})</td><td>16 μs (T_{GI2} + 2 × T_{FFT})</td><td>32 μs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ (17-4) In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

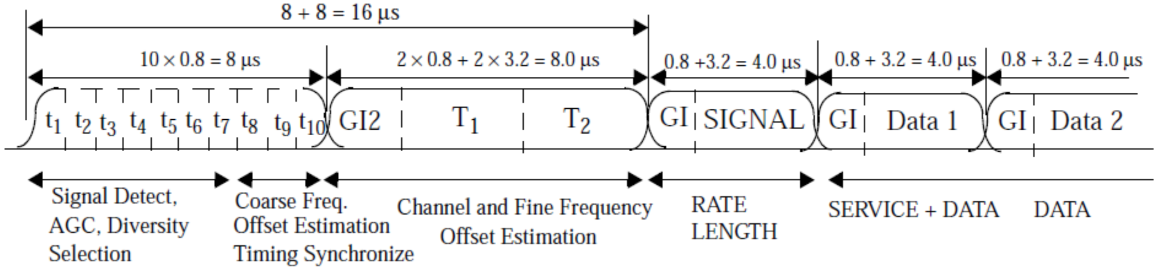


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

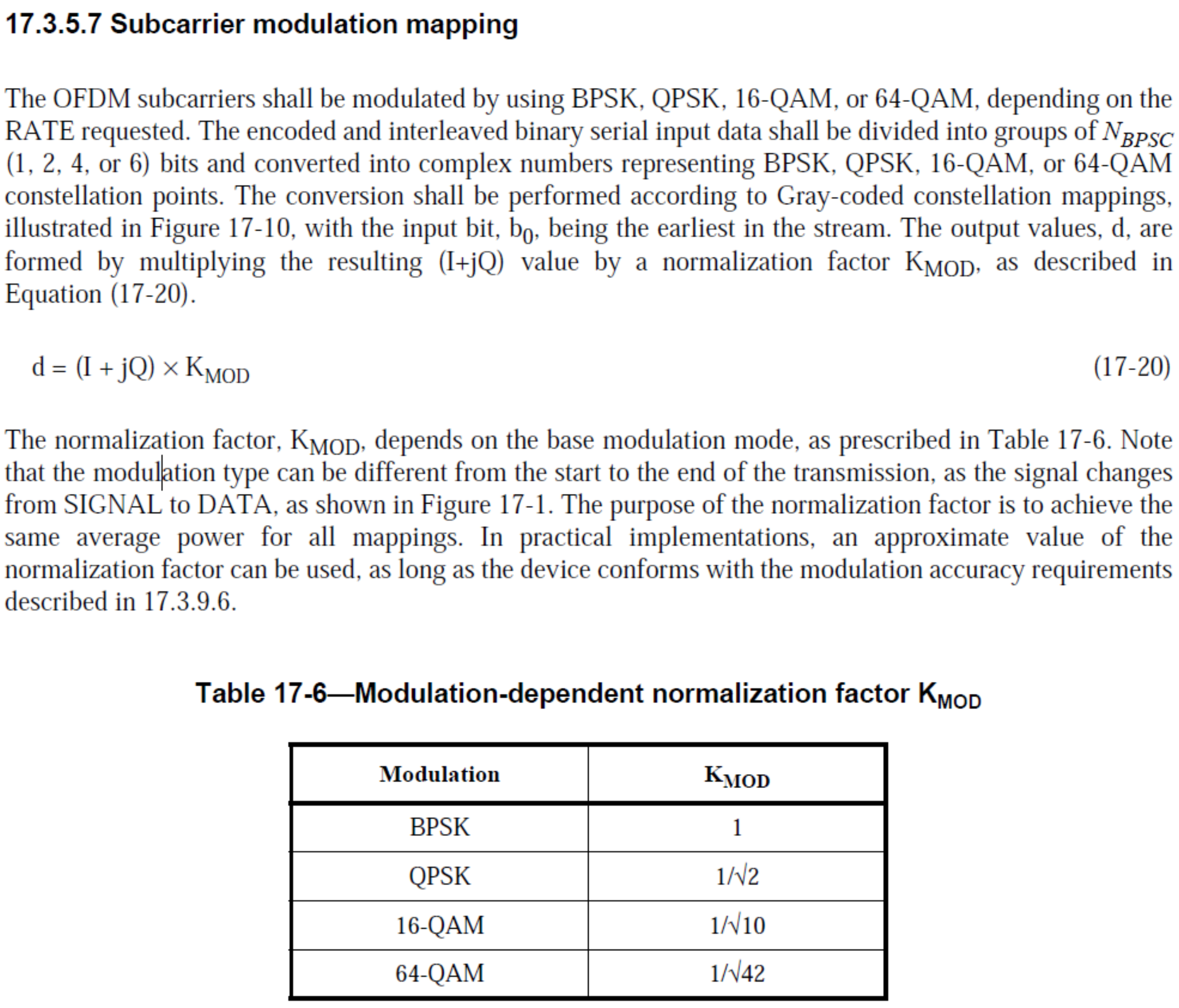
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}\,,\qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0,\\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

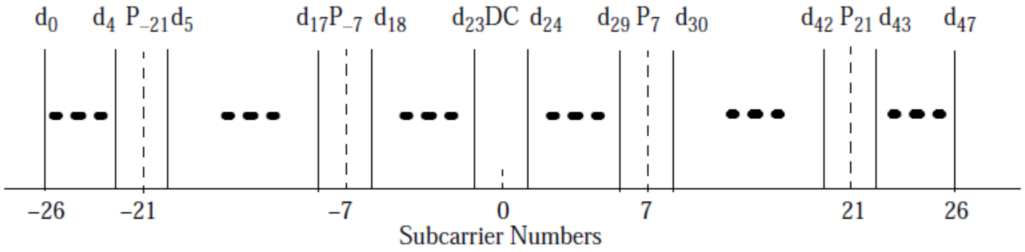


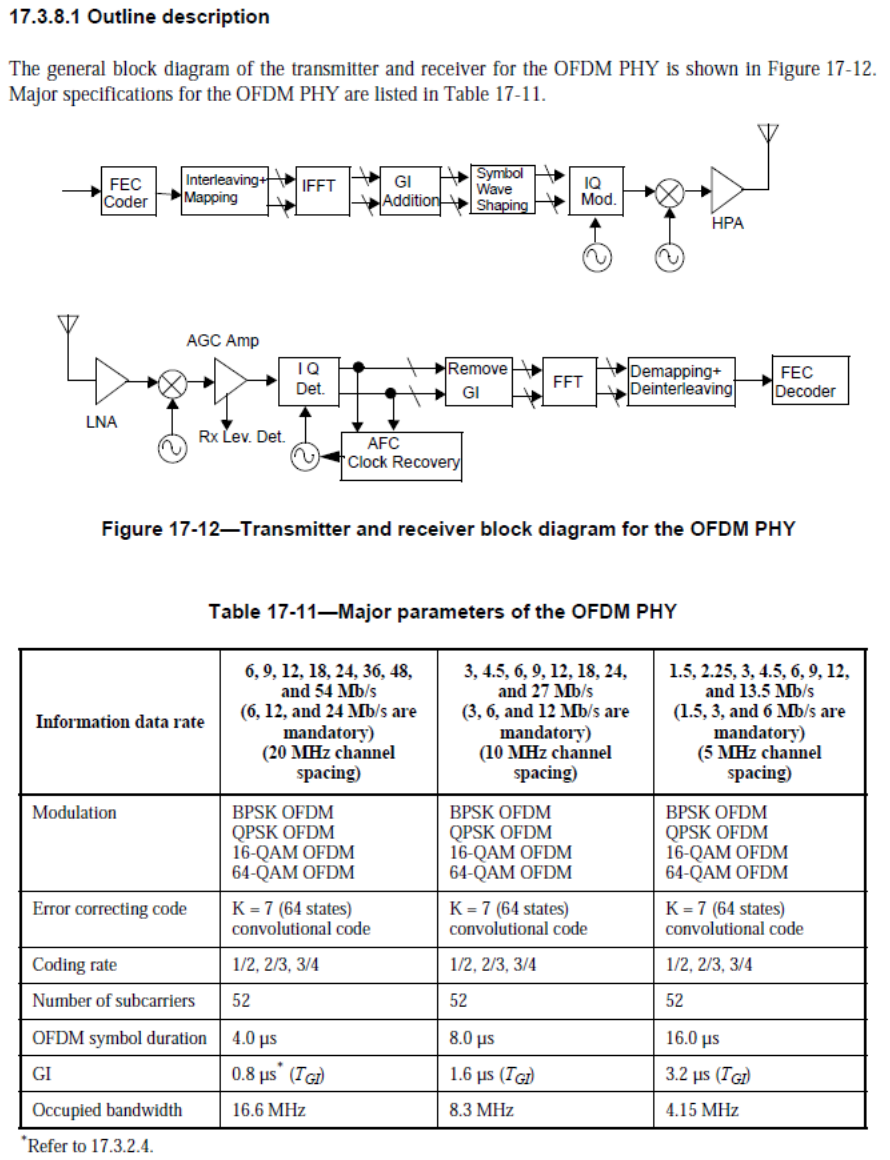
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

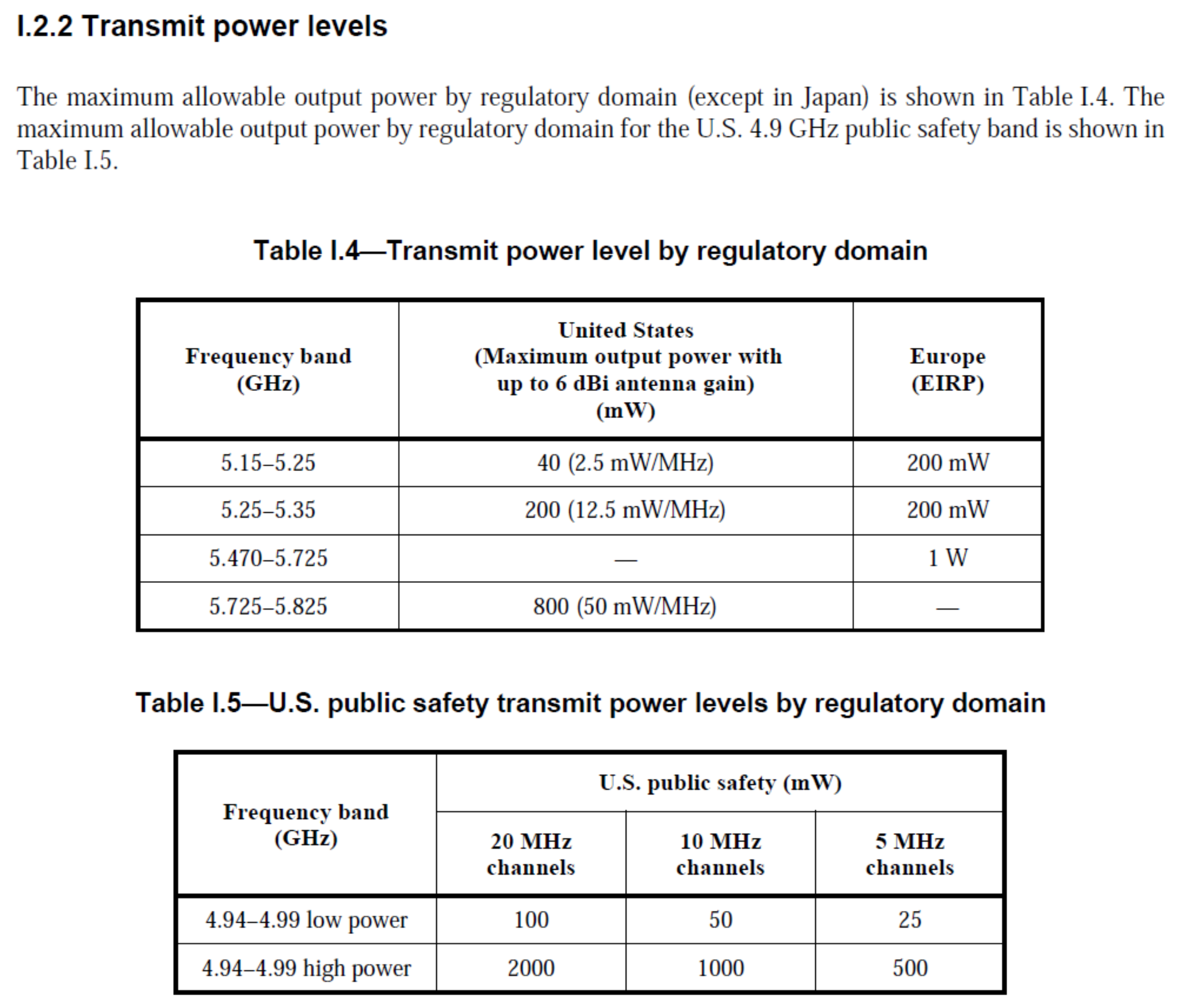
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

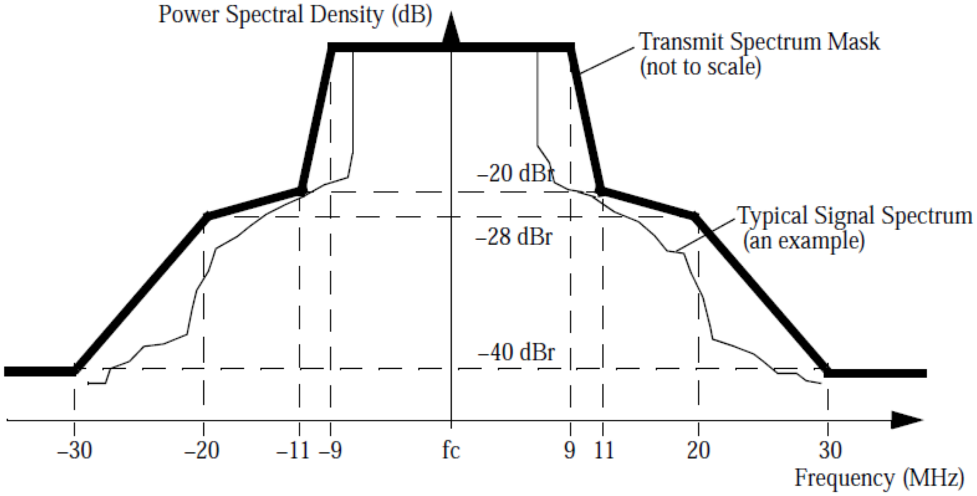
Table I.4—Transmit power level by regulatory domain

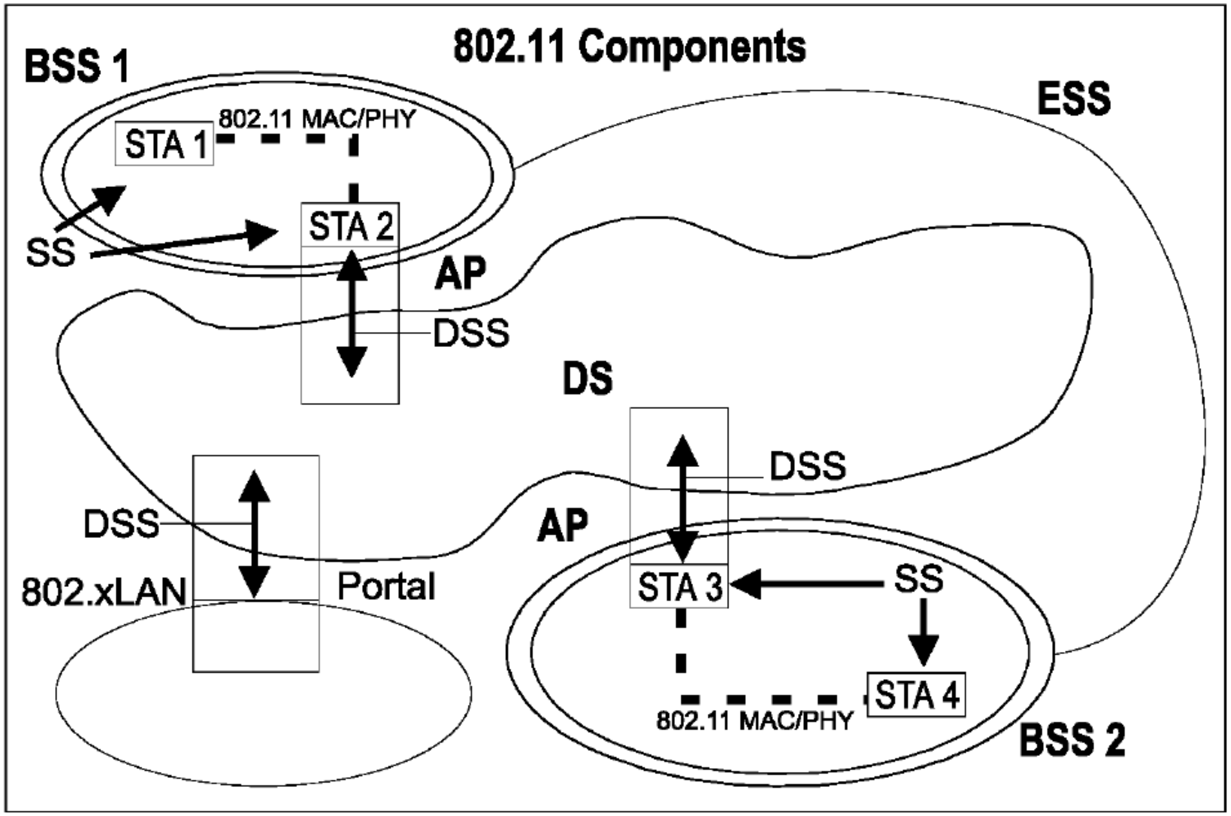
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

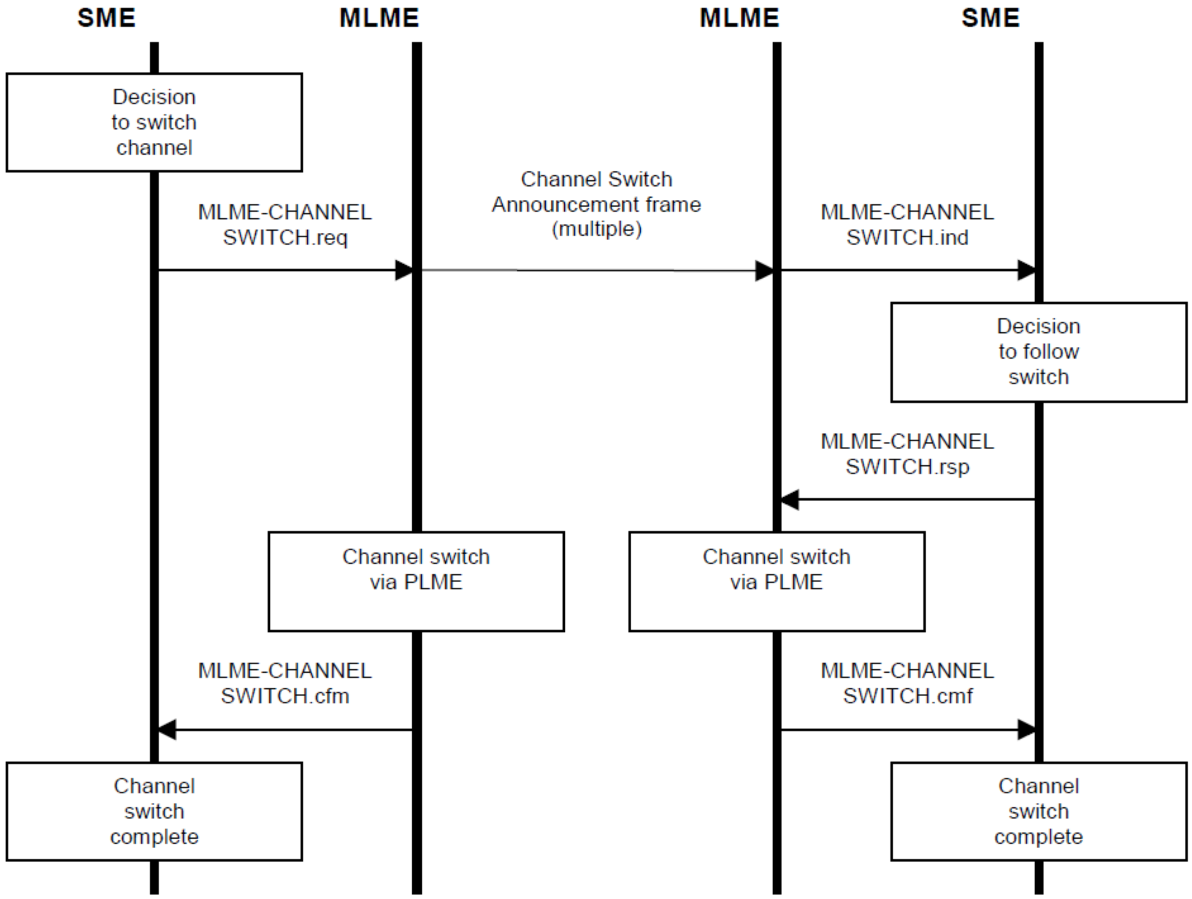
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

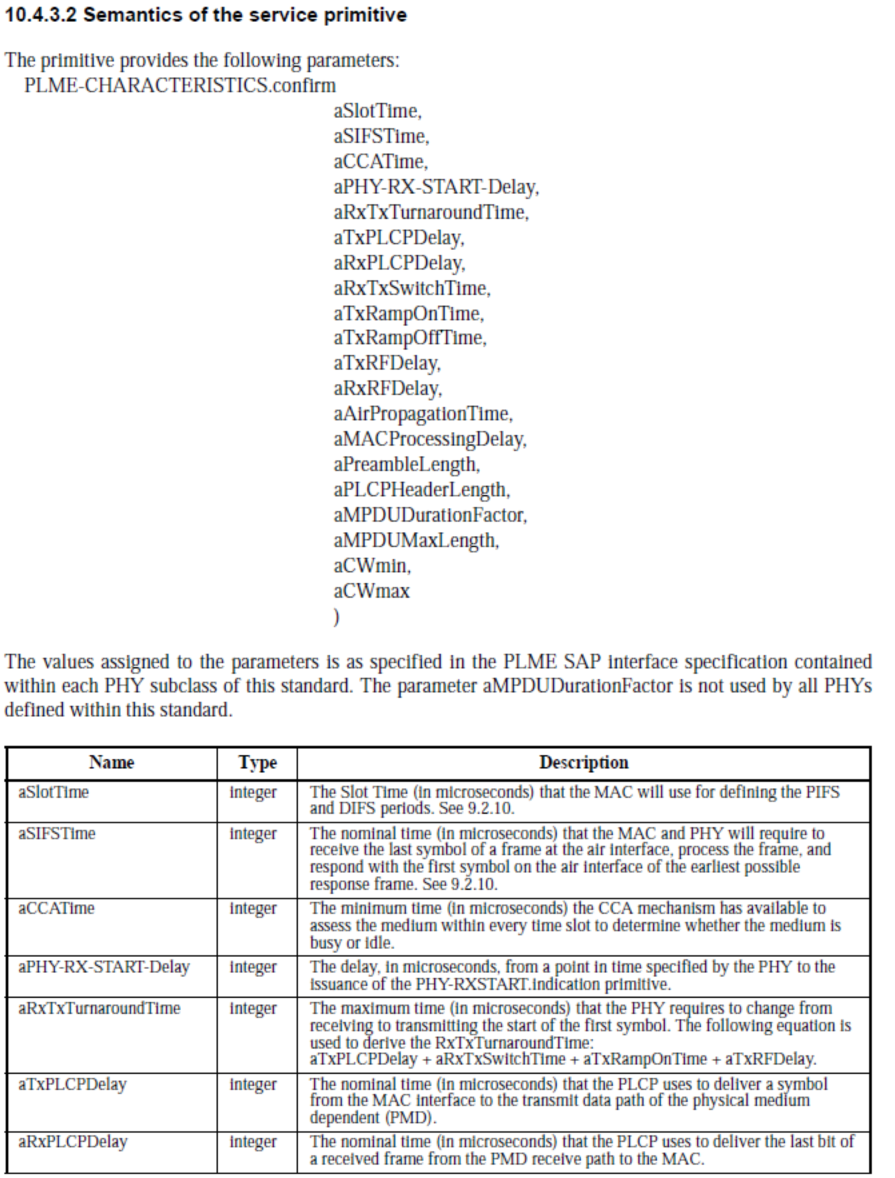
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.5] converting the second digital signal into a second analog signal using a second digital-to-analog converter, the second analog signal carrying the second data across a second frequency range;	802.11-2007 discloses "converting the second digital signal into a second analog signal using a second digital-to-analog converter, the second analog signal carrying the second data across a second frequency range." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

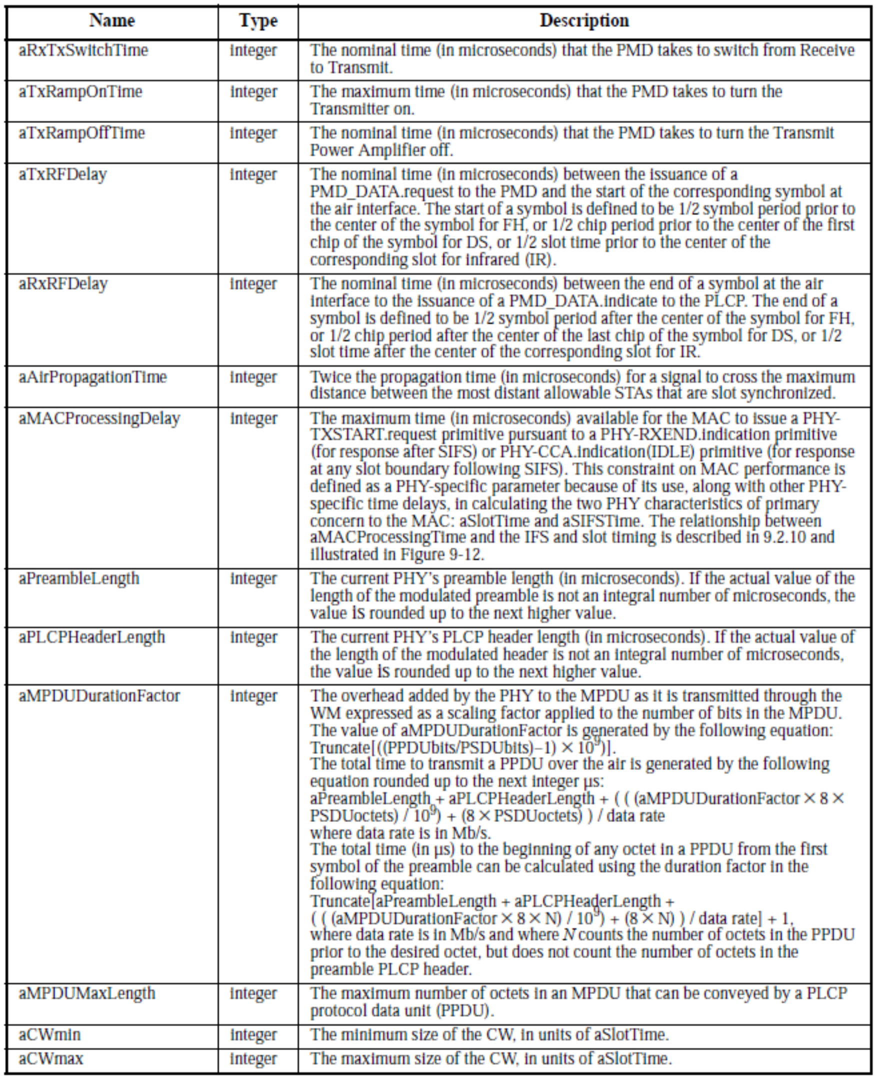
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



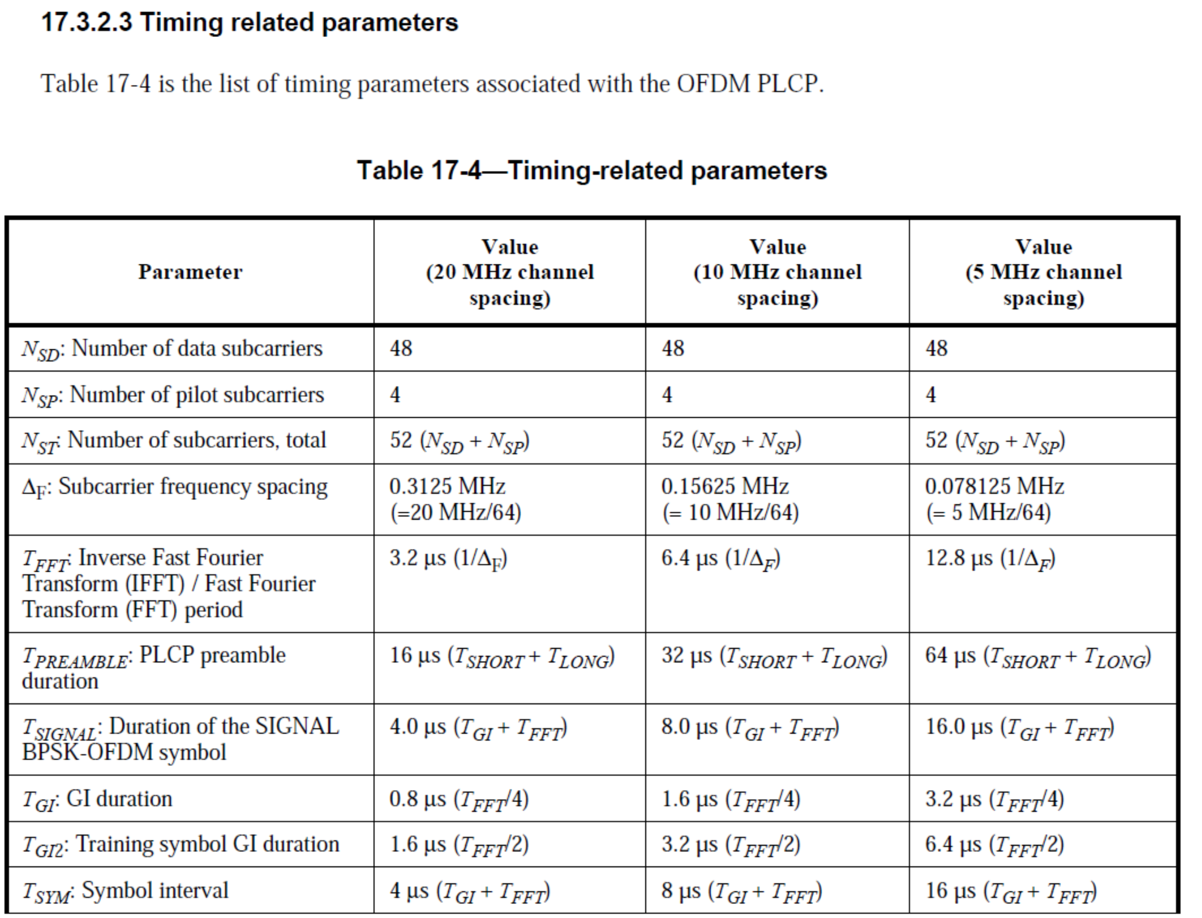
Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)−1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclo cked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007

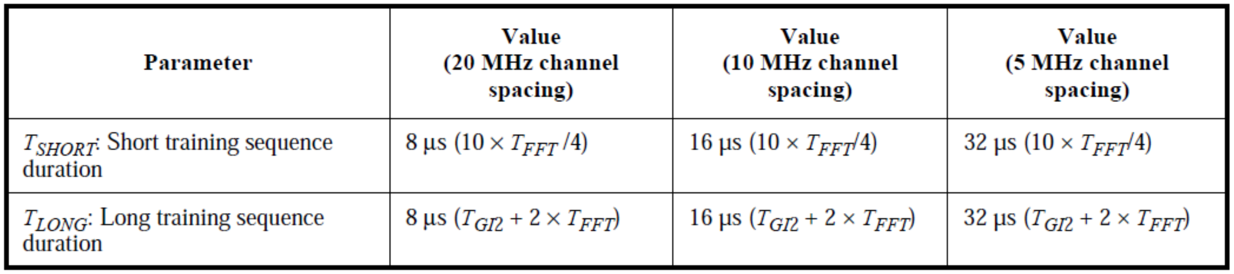


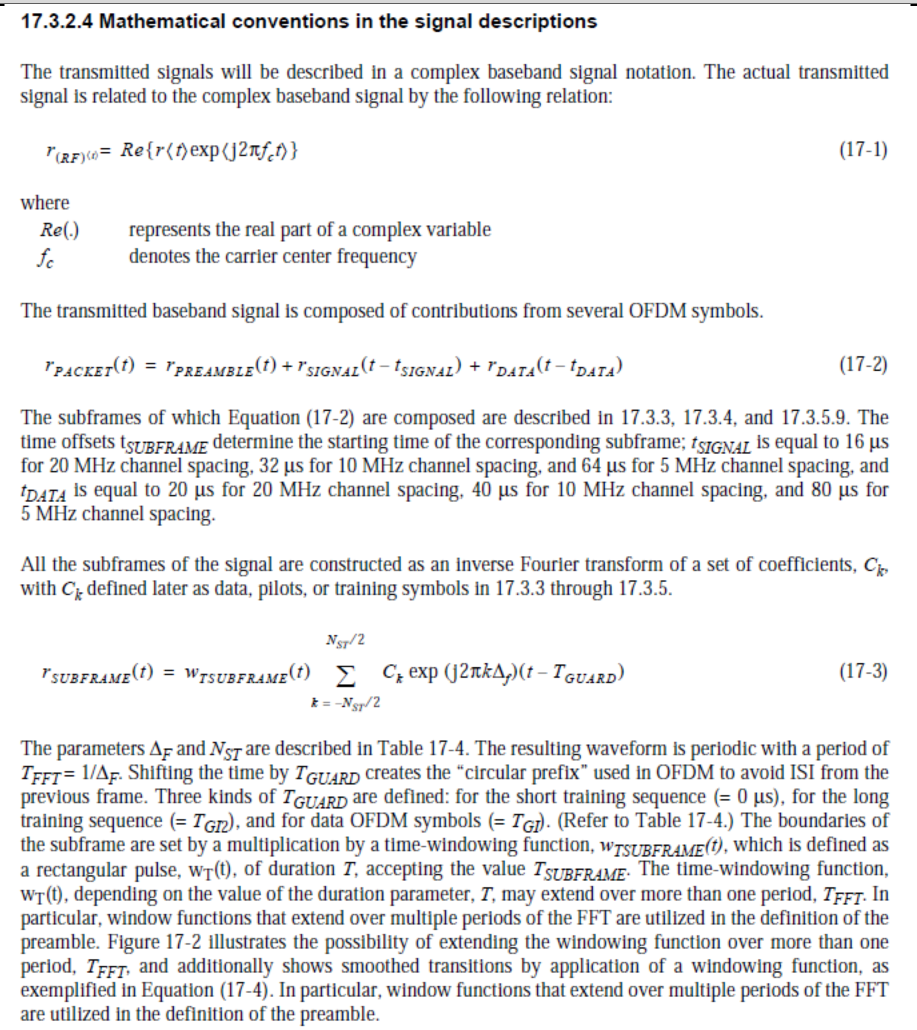
17.3.2.3 Timing related parameters

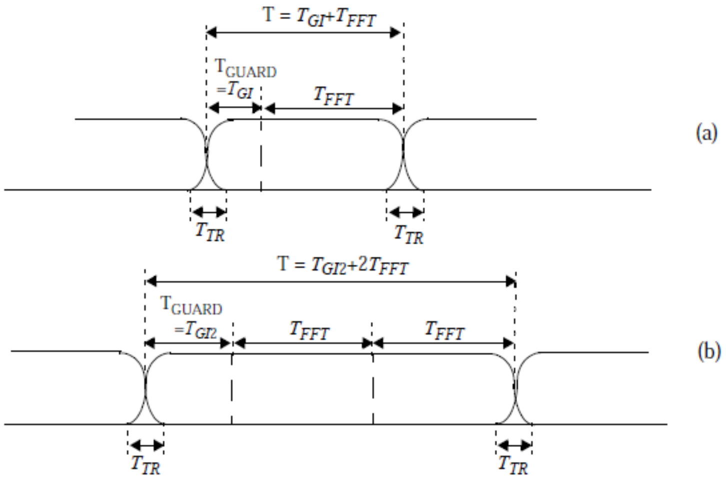
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

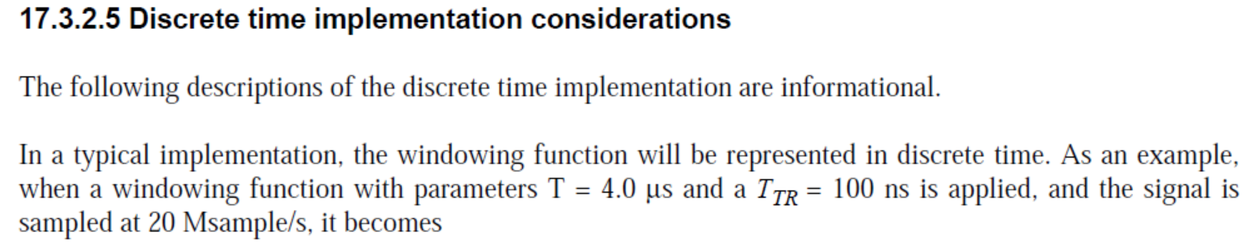
Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 μs (10 × T_{FFT} /4)</td><td>16 μs (10 × T_{FFT}/4)</td><td>32 μs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 μs (T_{GI2} + 2 × T_{FFT})</td><td>16 μs (T_{GI2} + 2 × T_{FFT})</td><td>32 μs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \tag{17-5}$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

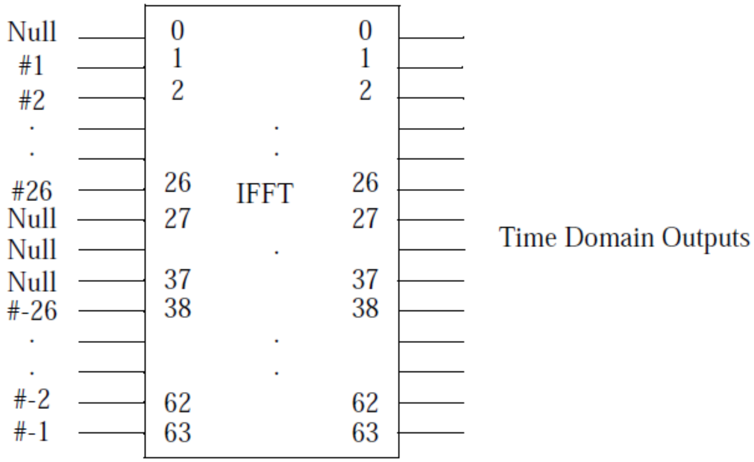
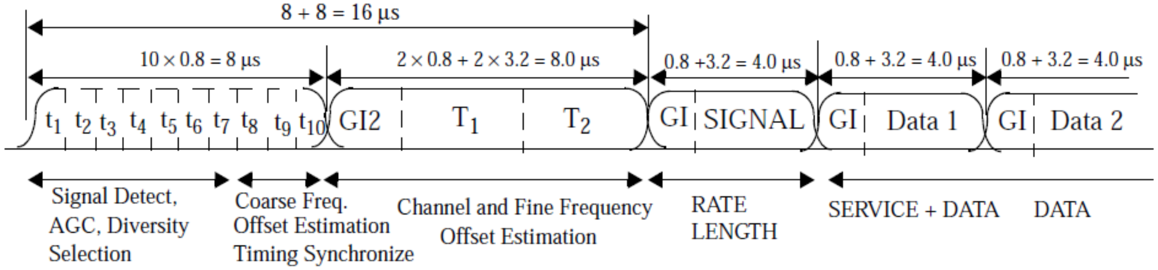


Figure 17-3—Inputs and outputs of inverse Fourier transform

See, e.g., 802.11-2007 § 17.3.2.5

</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

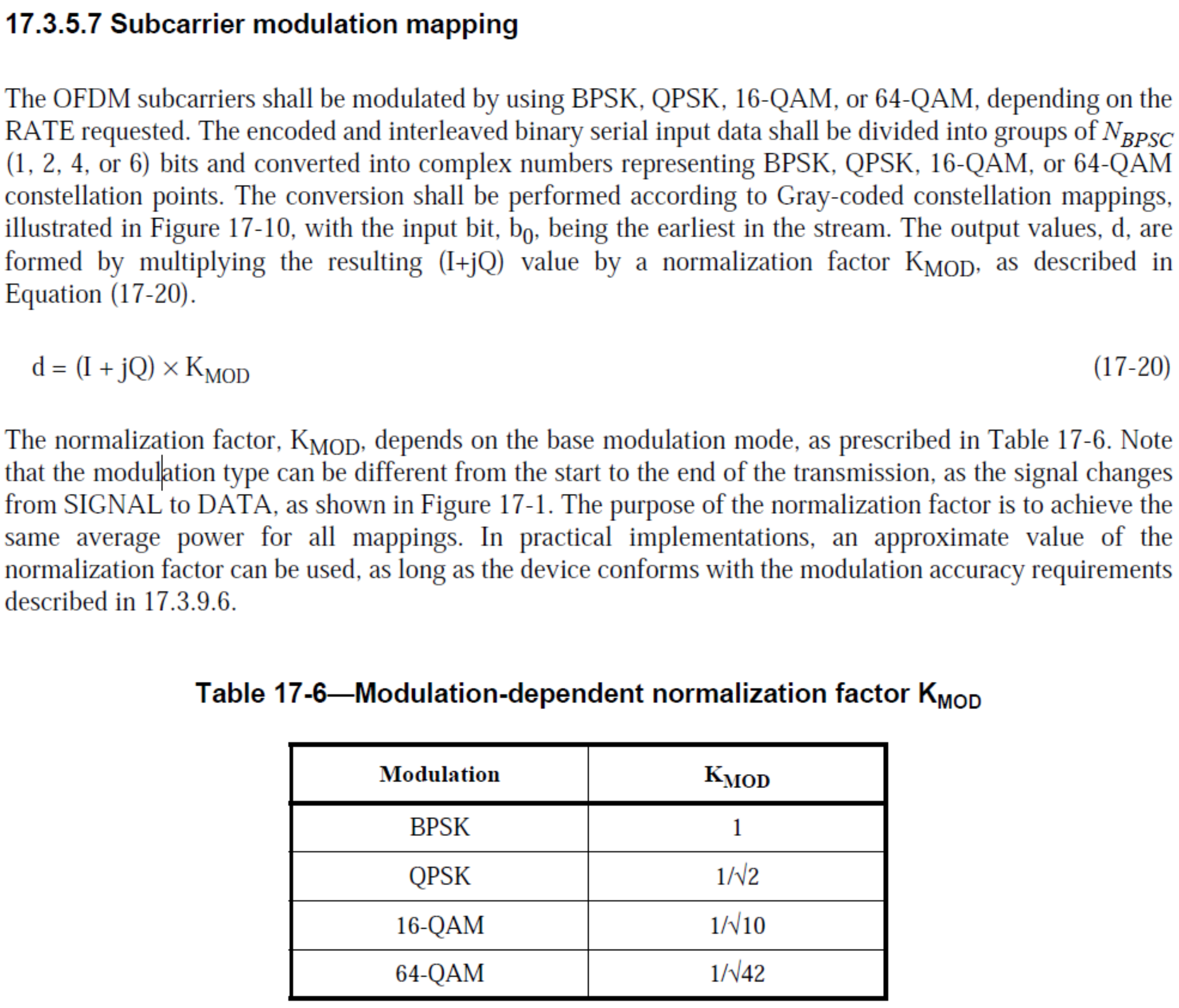
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$P_{-26,26} = \{0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

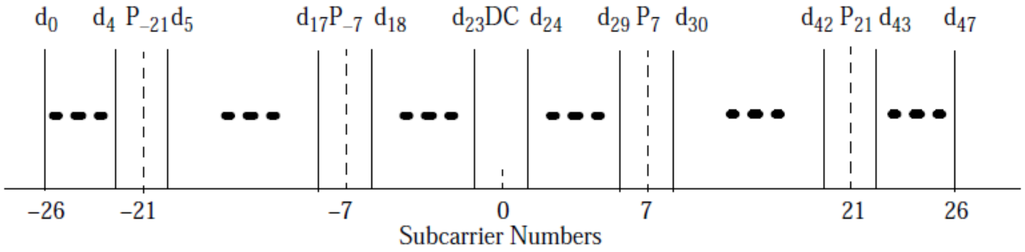


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

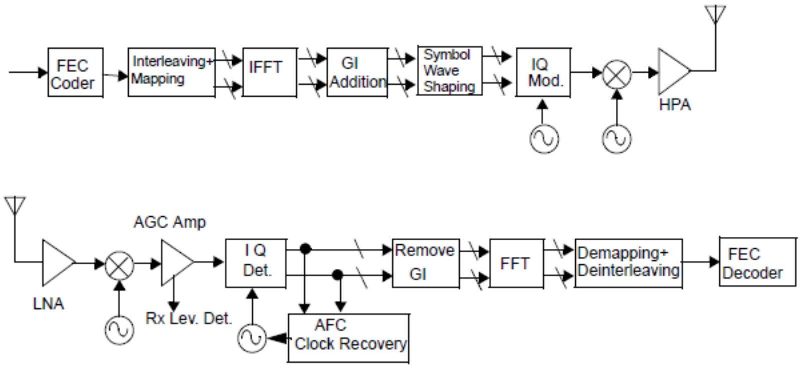


Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

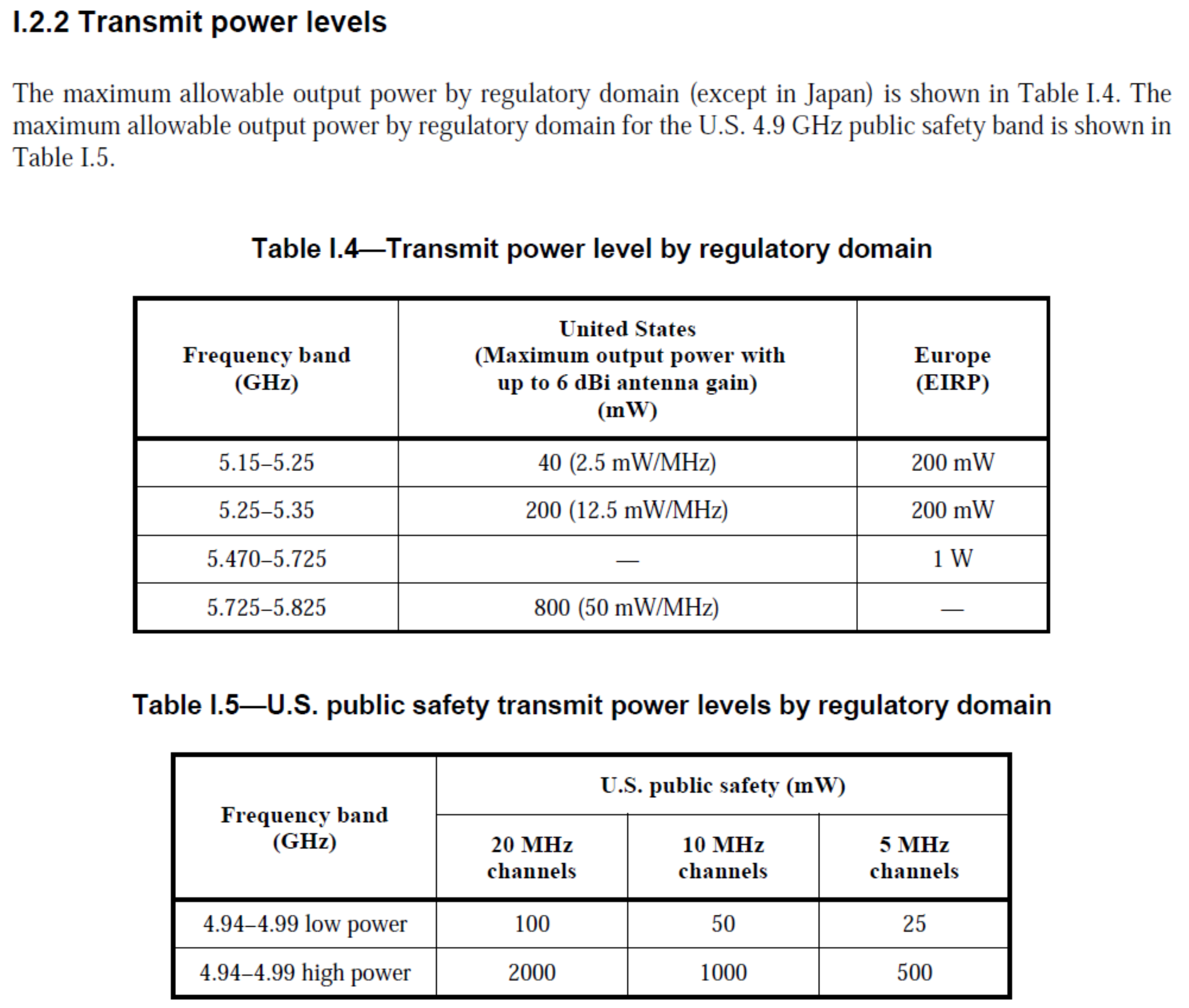
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs[*] (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

[*] Refer to 17.3.2.4.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

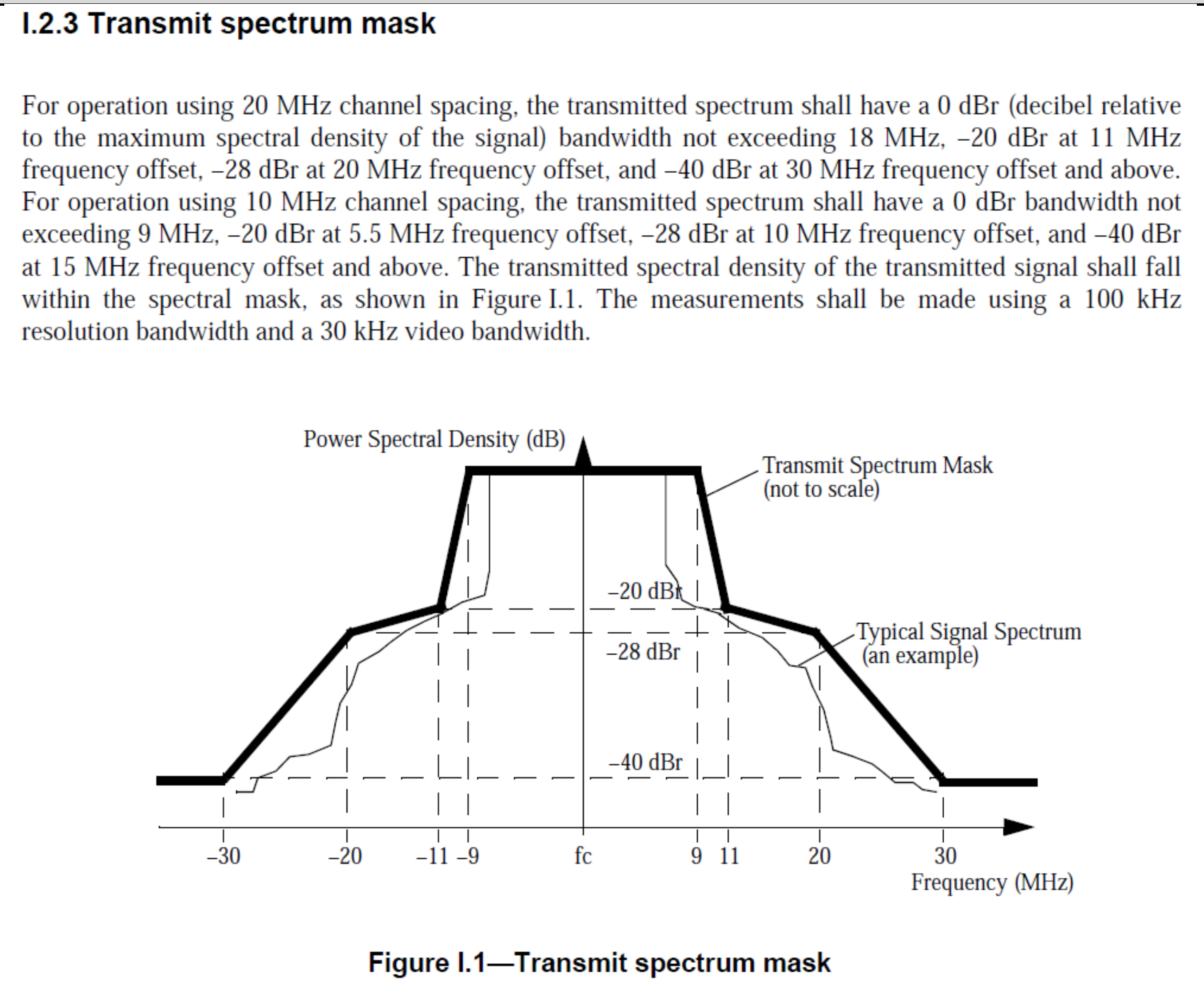
Table I.4—Transmit power level by regulatory domain

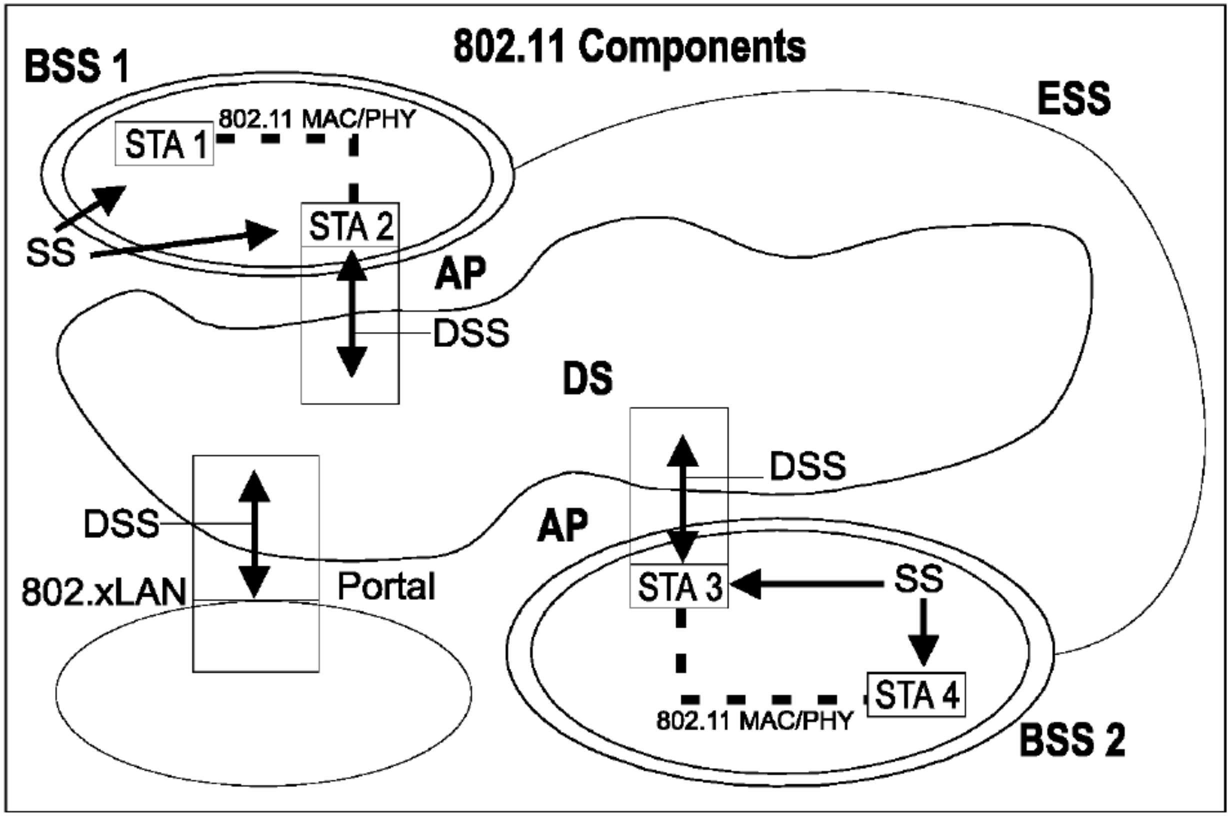
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

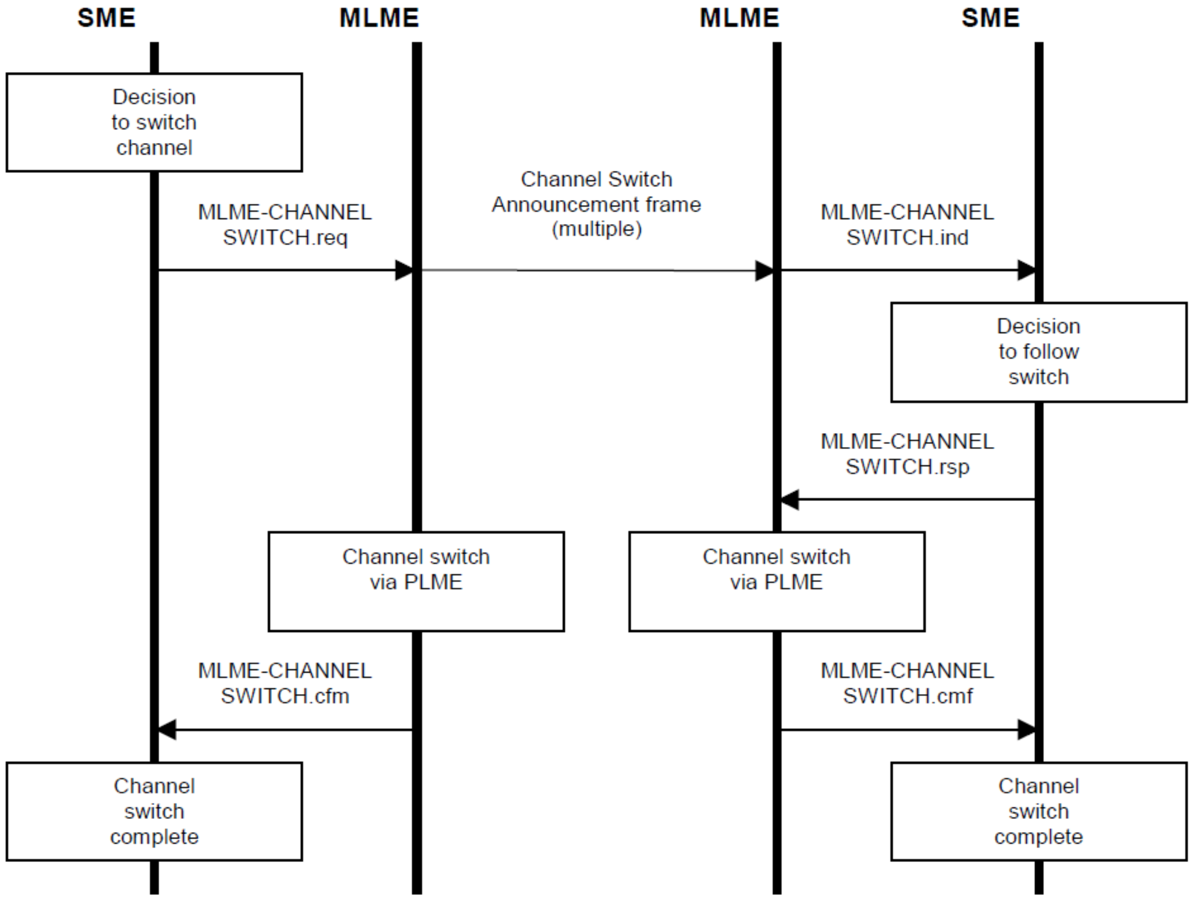
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.6] up-converting the first analog signal to a first RF center frequency to produce a first up-converted analog signal, wherein the first up-converted analog signal comprises a first up-converted frequency range from the first RF center frequency minus one-half the first frequency range to the first RF center frequency plus one-half the first frequency range;	802.11-2007 discloses "up-converting the first analog signal to a first RF center frequency to produce a first up-converted analog signal, wherein the first up-converted analog signal comprises a first up-converted frequency range from the first RF center frequency minus one-half the first frequency range to the first RF center frequency plus one-half the first frequency range." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

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	areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is

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	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

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	to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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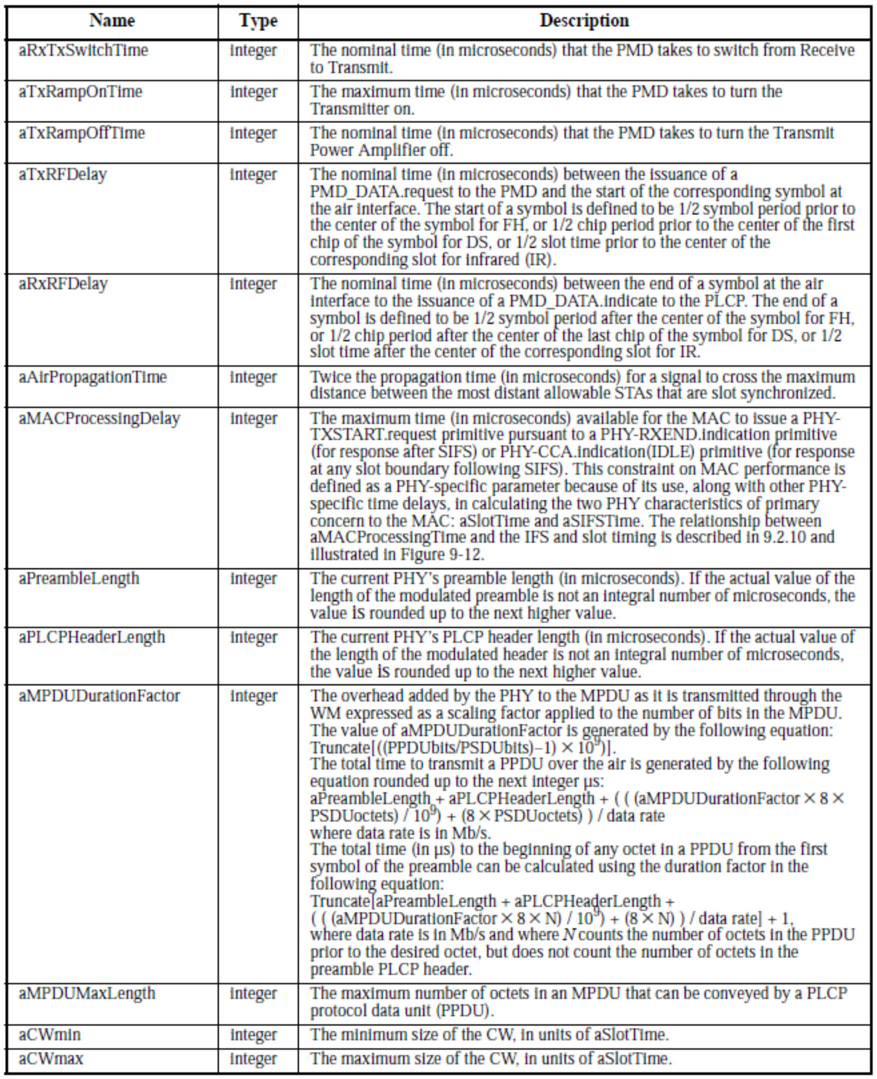

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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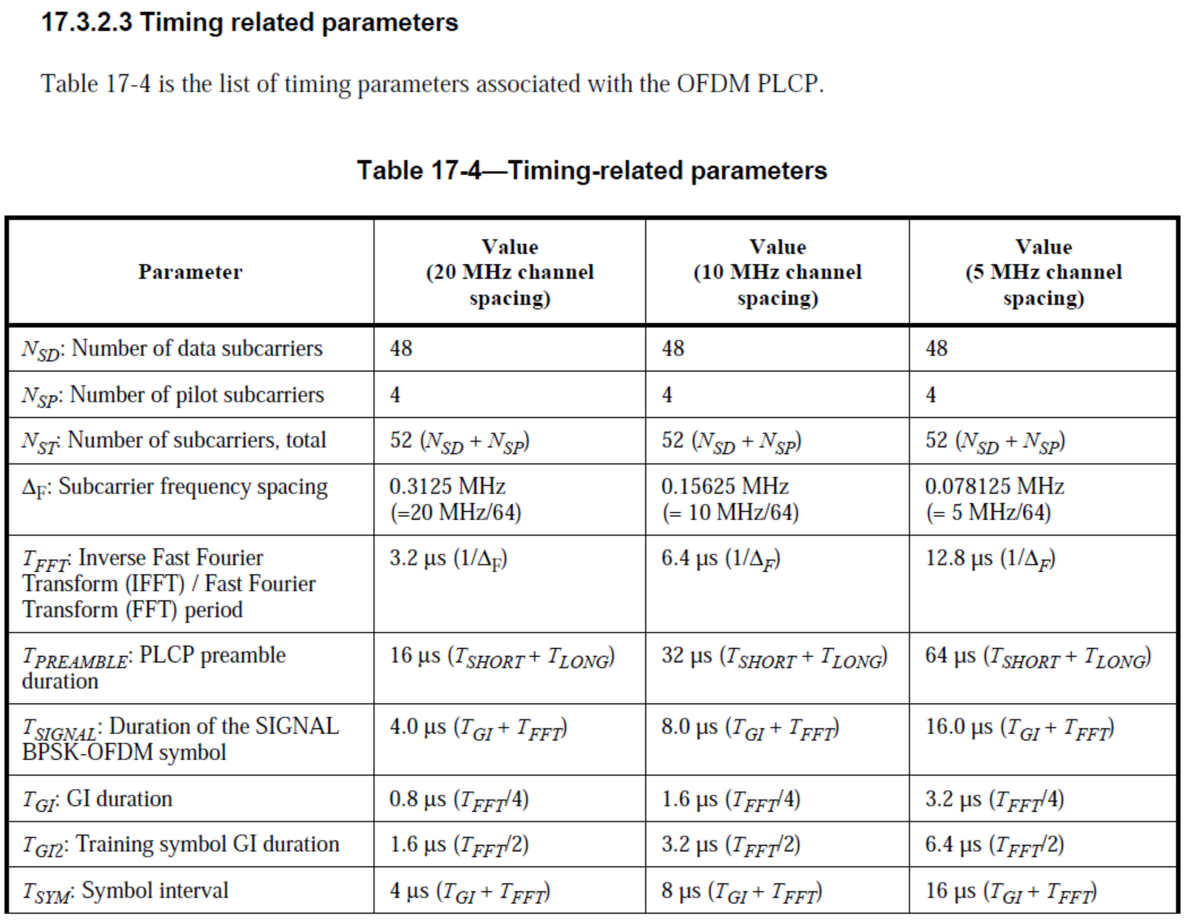
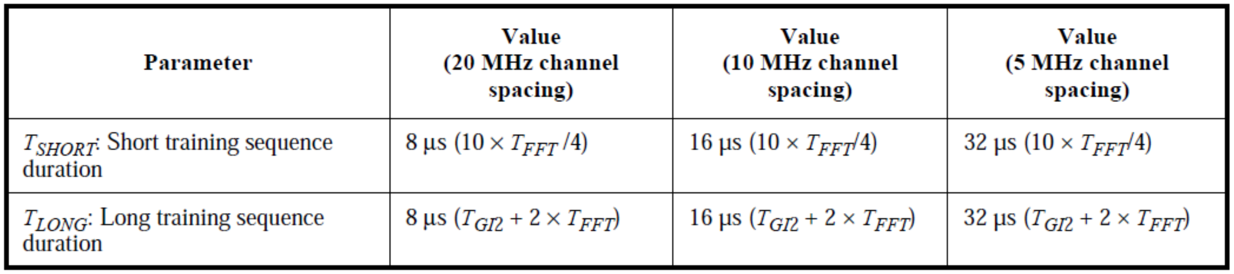
	

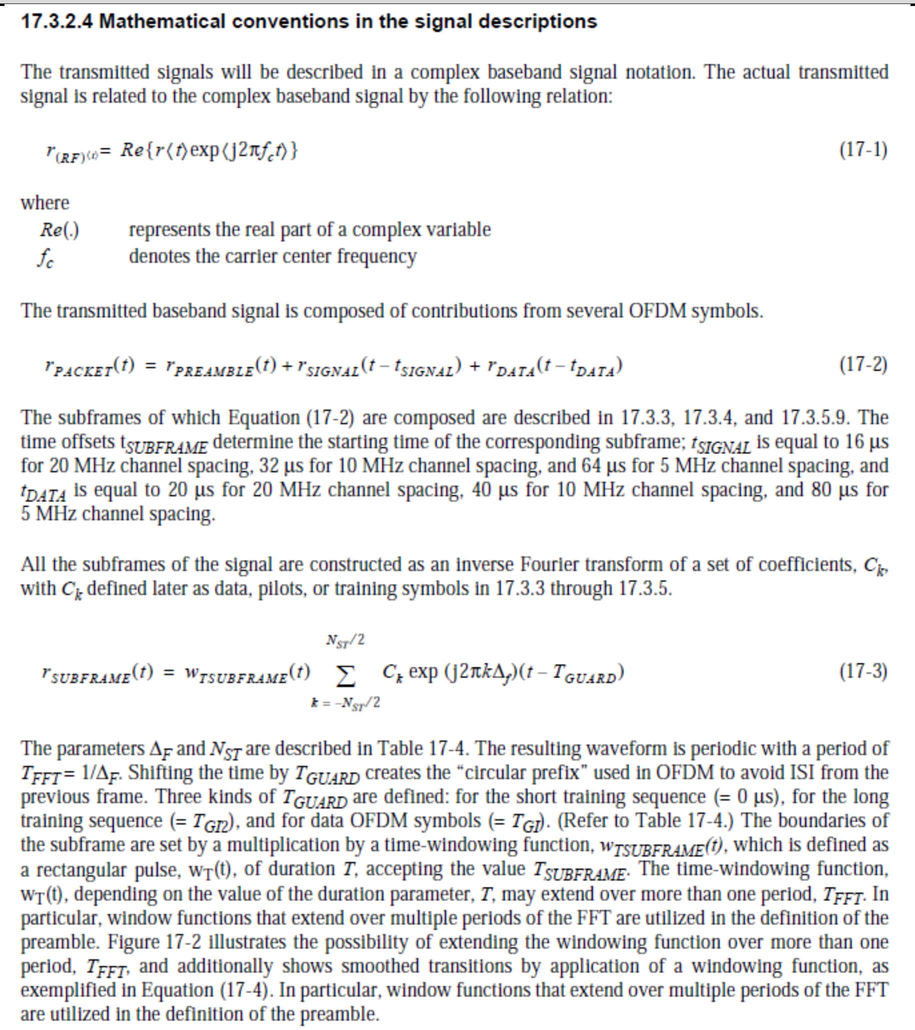
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_{F}: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_{\mathrm{F}}$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$	represents the real part of a complex variable
f_c	denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

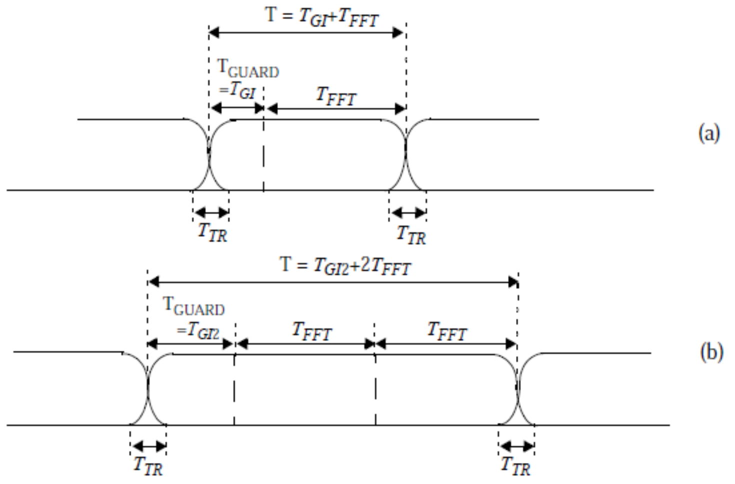
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

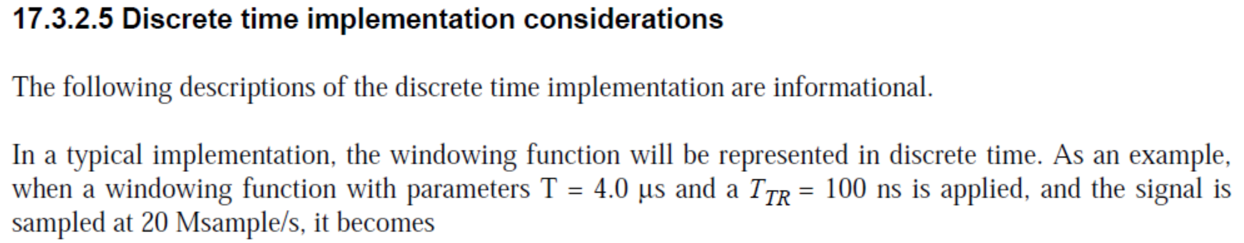
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

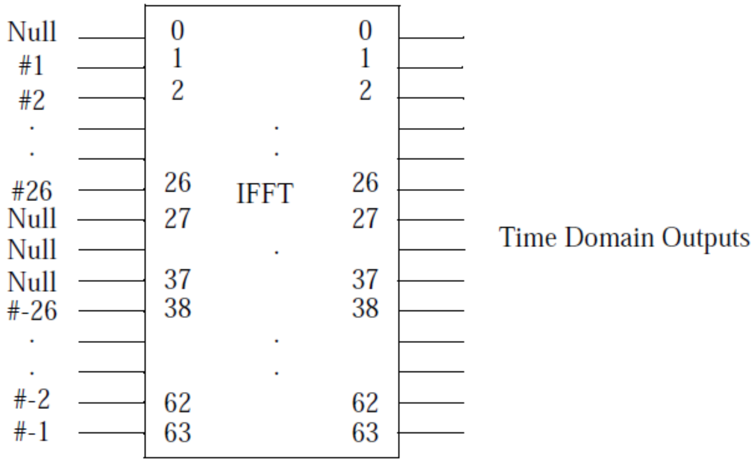
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

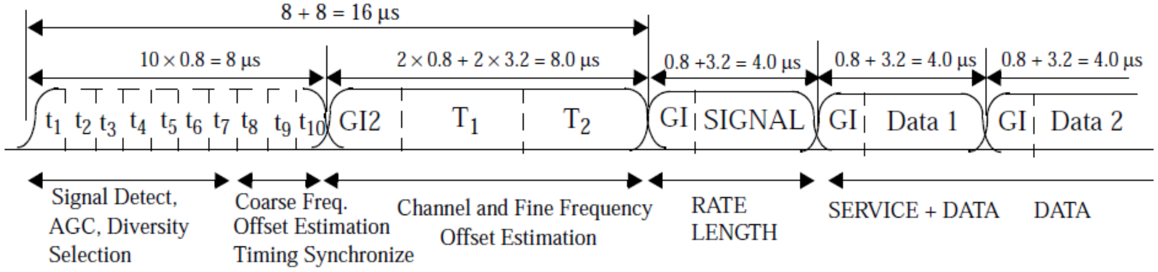
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

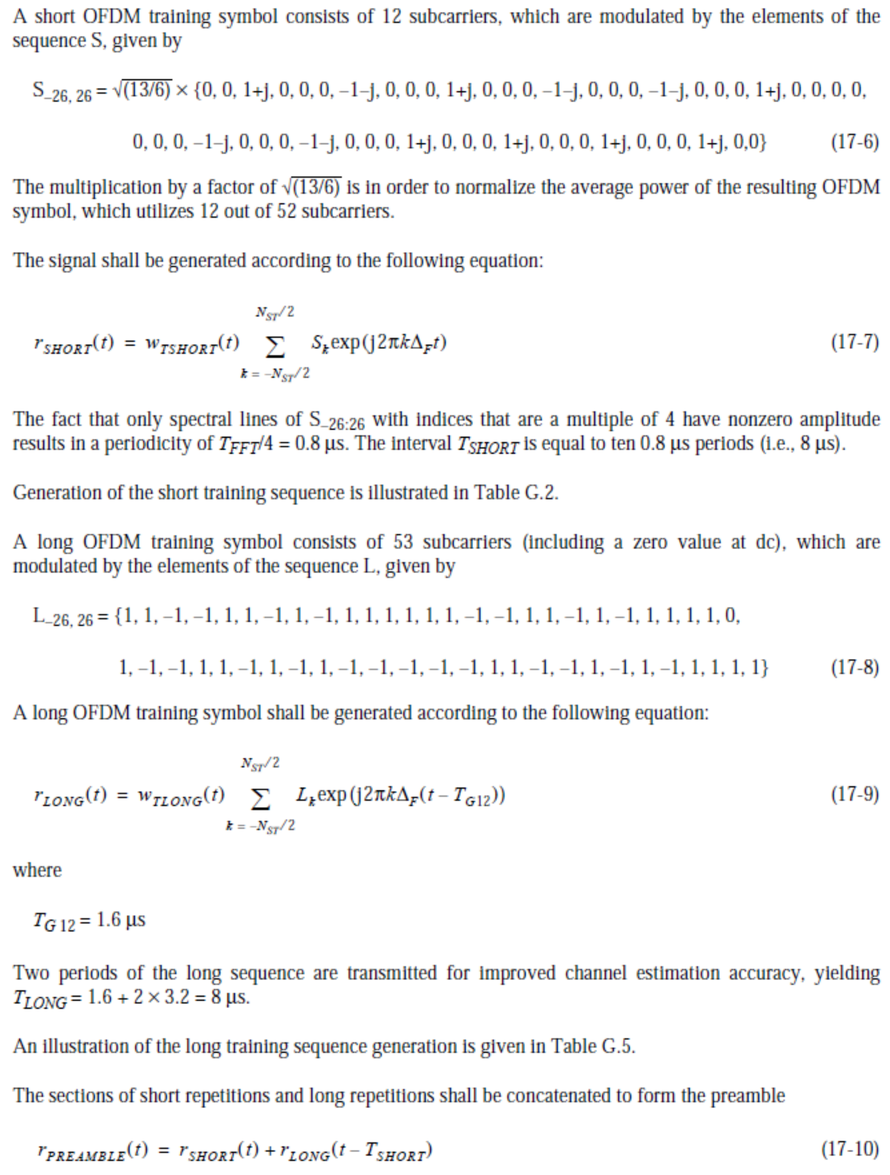
The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence ($= T_{GI2}$), and for data OFDM symbols ($= T_{GI}$). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

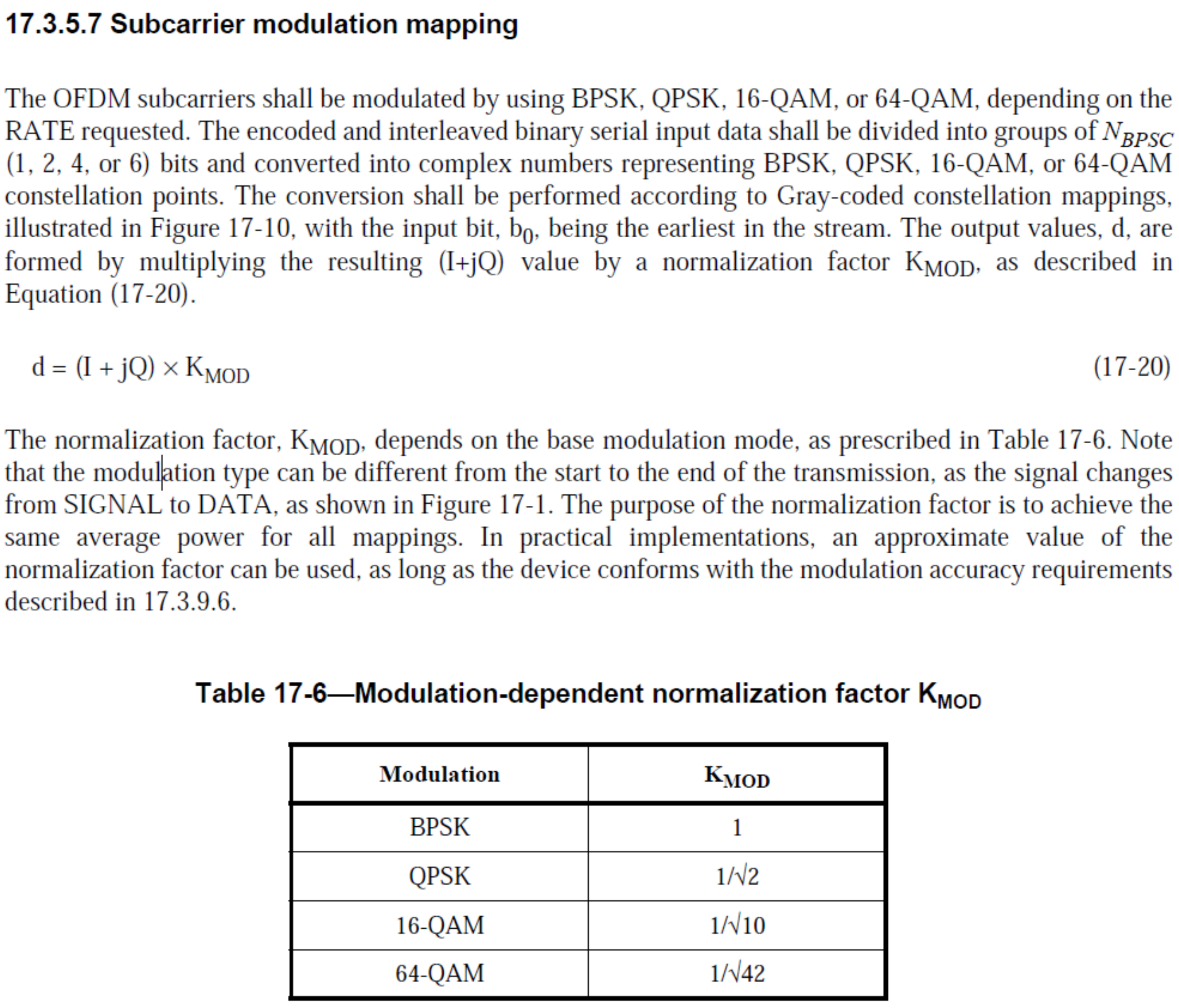
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,\,n} \equiv d_{k\,+\,N_{SD}\,\times\,n}\,, \qquad k = 0,\, \ldots\, N_{SD} - 1,\ n = 0,\, \ldots\, N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,\,n}(t) \;=\; w_{TSYM}(t)\left(\sum_{k\,=\,0}^{N_{SD}-1} d_{k,\,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n\,+\,1}\sum_{k\,=\,-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) \;=\; \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,\,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

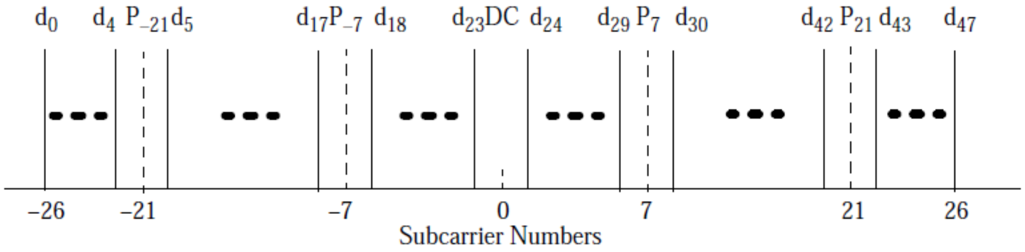


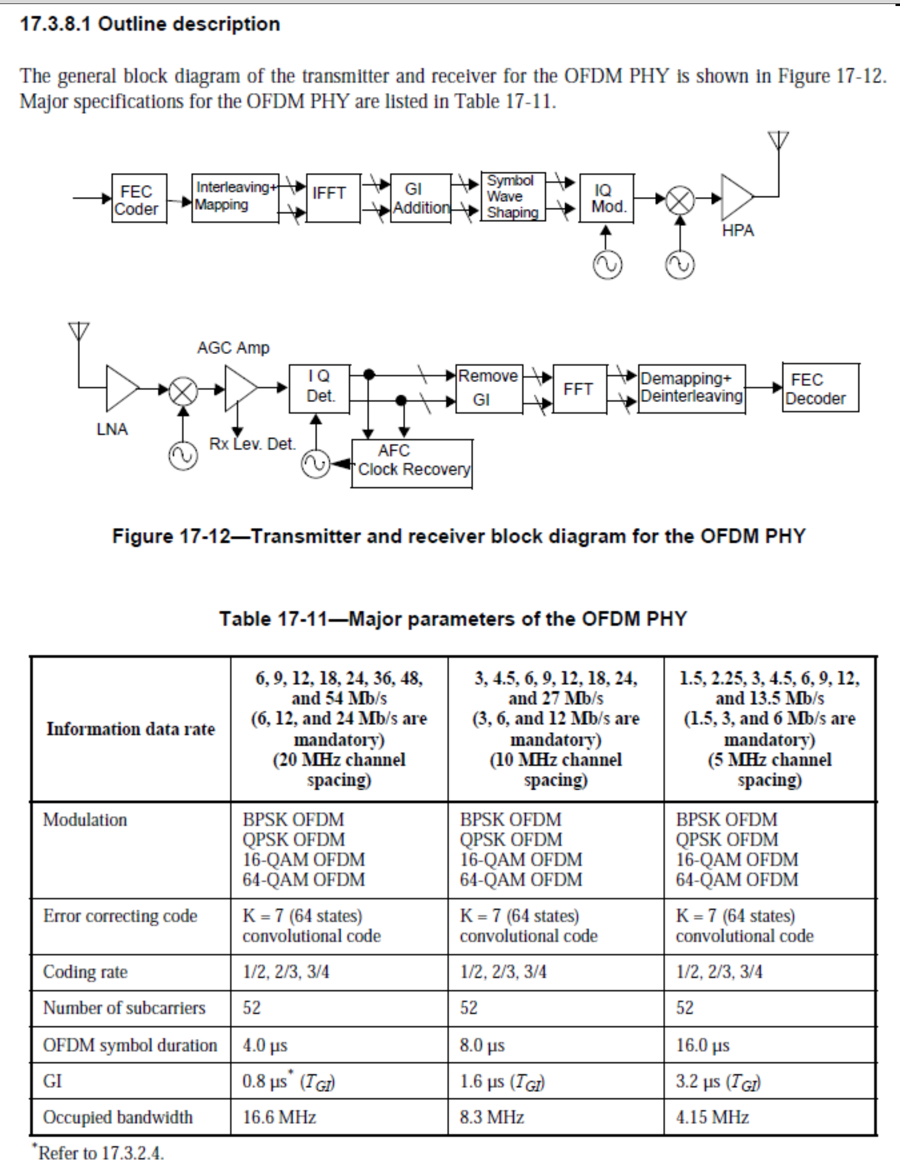
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

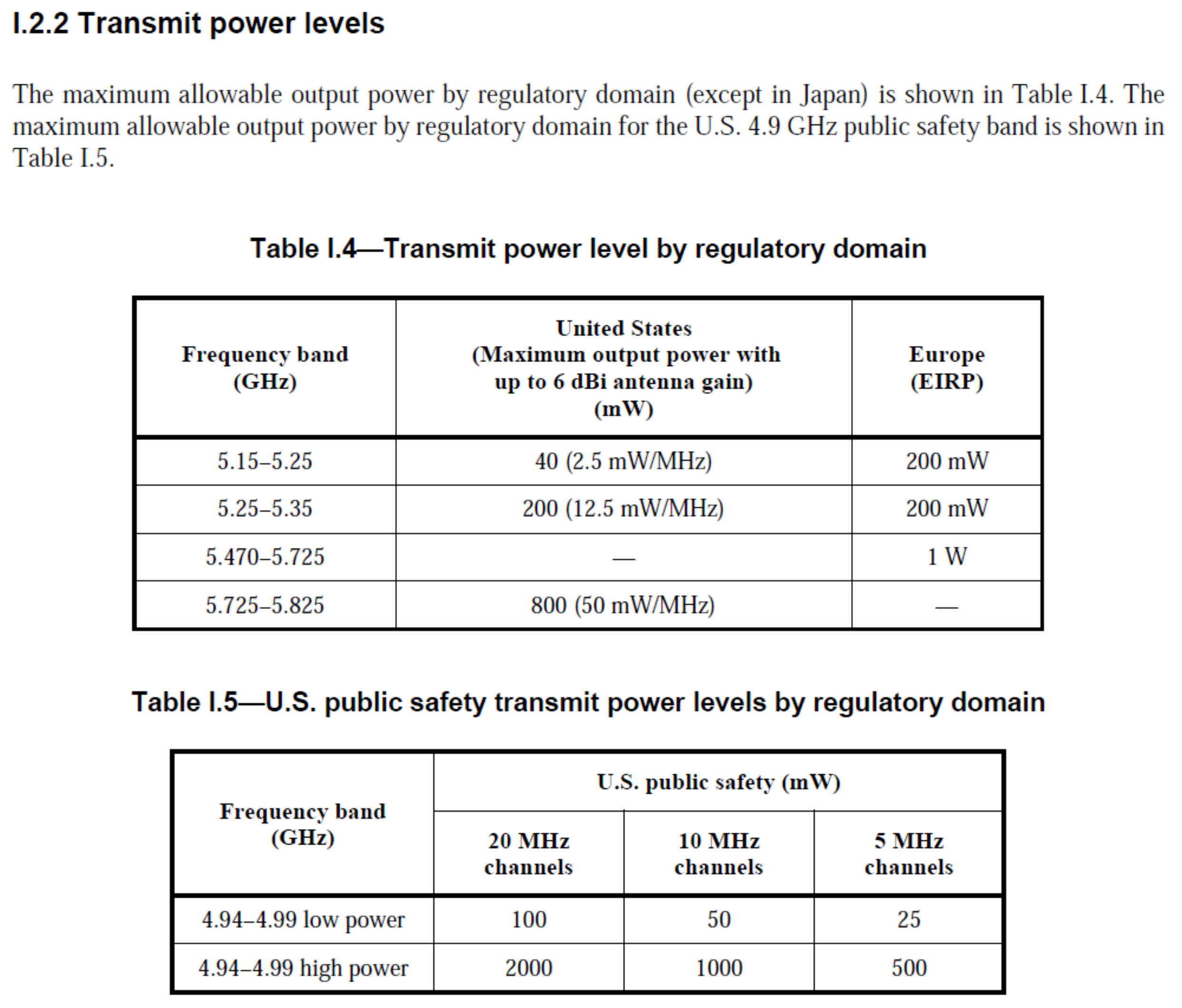
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

Table I.4—Transmit power level by regulatory domain

Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

I.2.3 Transmit spectrum mask

For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

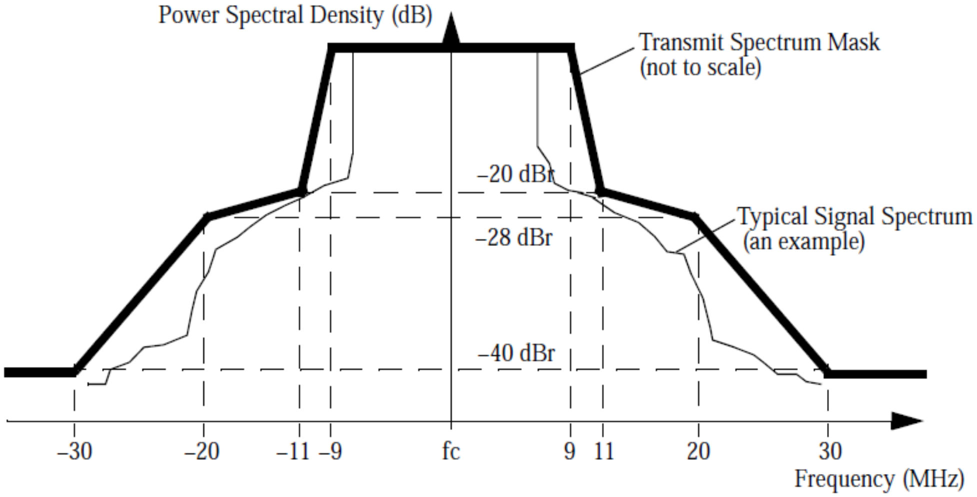


Figure I.1—Transmit spectrum mask

See, e.g., 802.11-2007 § I.2.3

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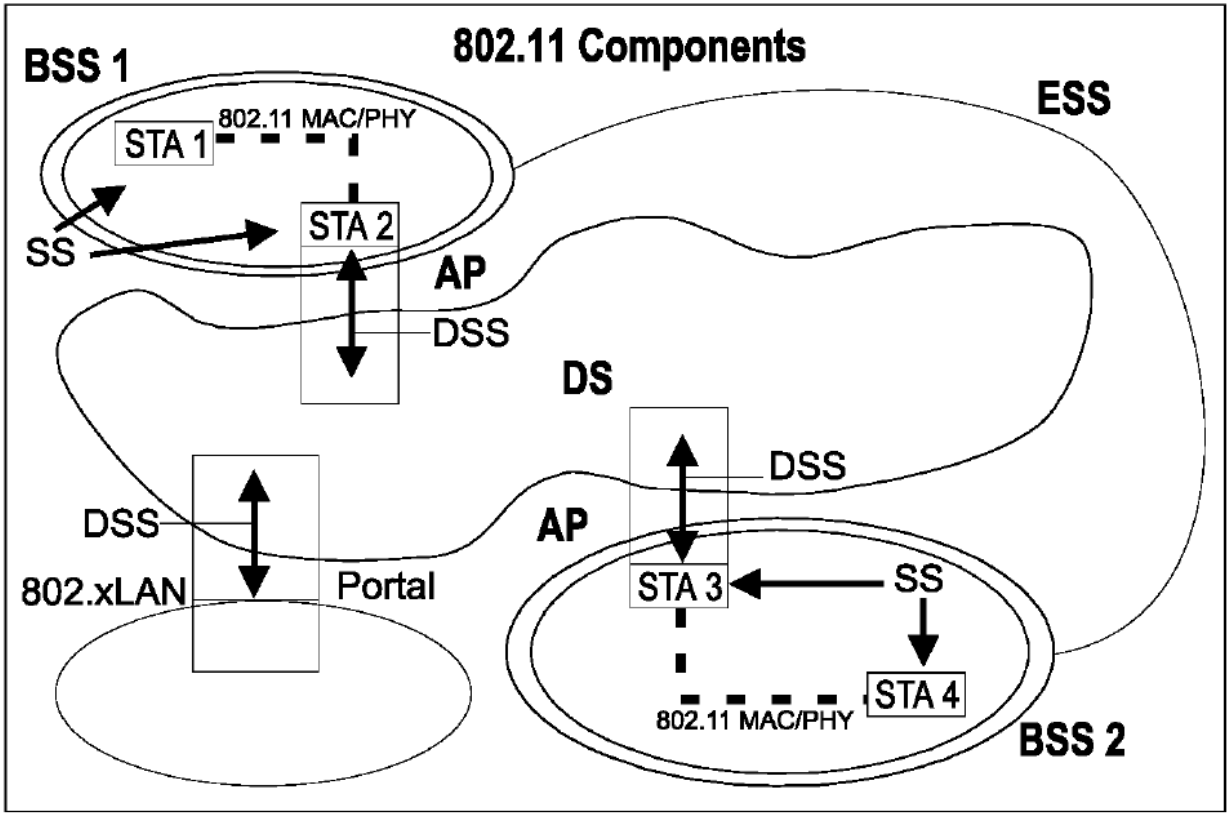
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

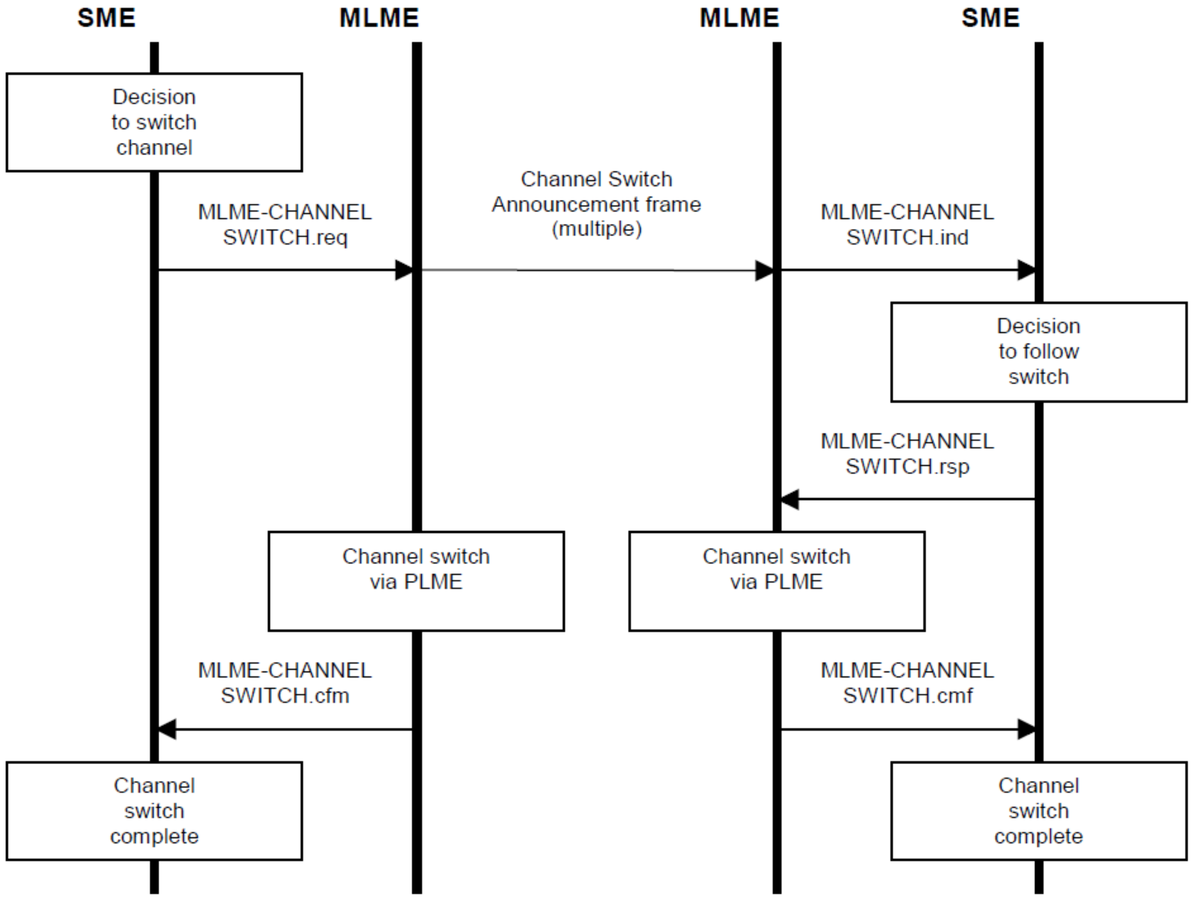


Figure 10-6—Channel switch

See, e.g., 802.11-2007 Figure 10-6

Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

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</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.7] up-converting the second analog signal to a second RF center frequency greater than the first center RF frequency to produce a second up-converted analog signal, wherein the second up-converted analog signal comprises a second up-converted frequency range from the second RF center frequency minus one-half the second frequency range to the second RF center frequency plus one-half the second frequency range, and wherein a frequency difference between the first RF center frequency and the second RF center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range;	802.11-2007 discloses “up-converting the second analog signal to a second RF center frequency greater than the first center RF frequency to produce a second up-converted analog signal, wherein the second up-converted analog signal comprises a second up-converted frequency range from the second RF center frequency minus one-half the second frequency range to the second RF center frequency plus one-half the second frequency range, and wherein a frequency difference between the first RF center frequency and the second RF center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts**

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	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2

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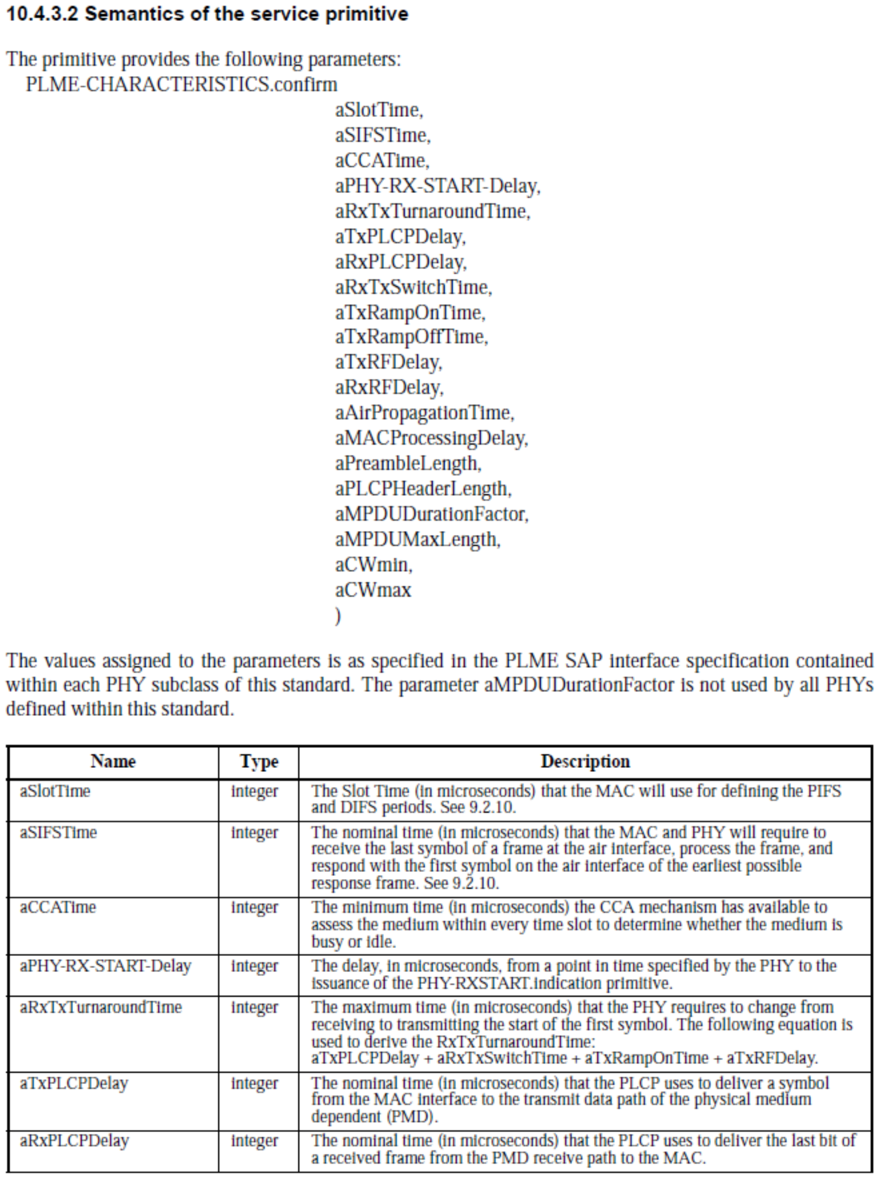
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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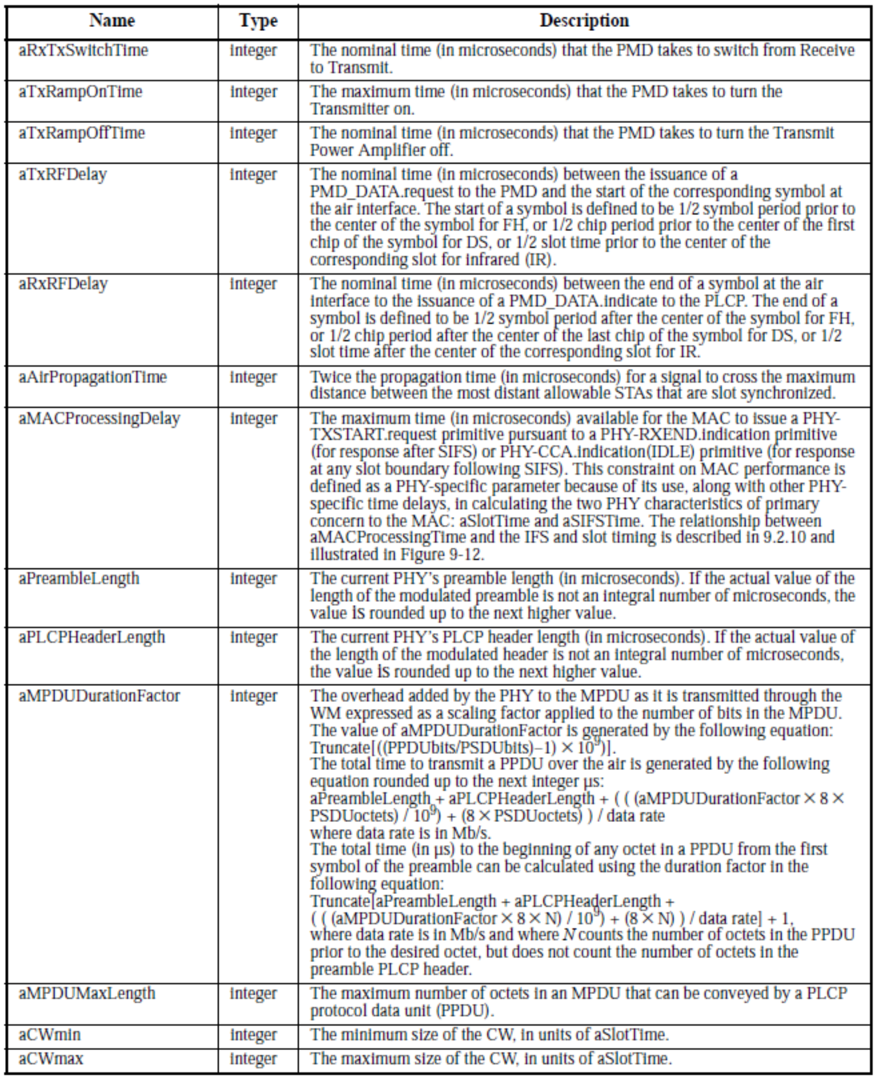

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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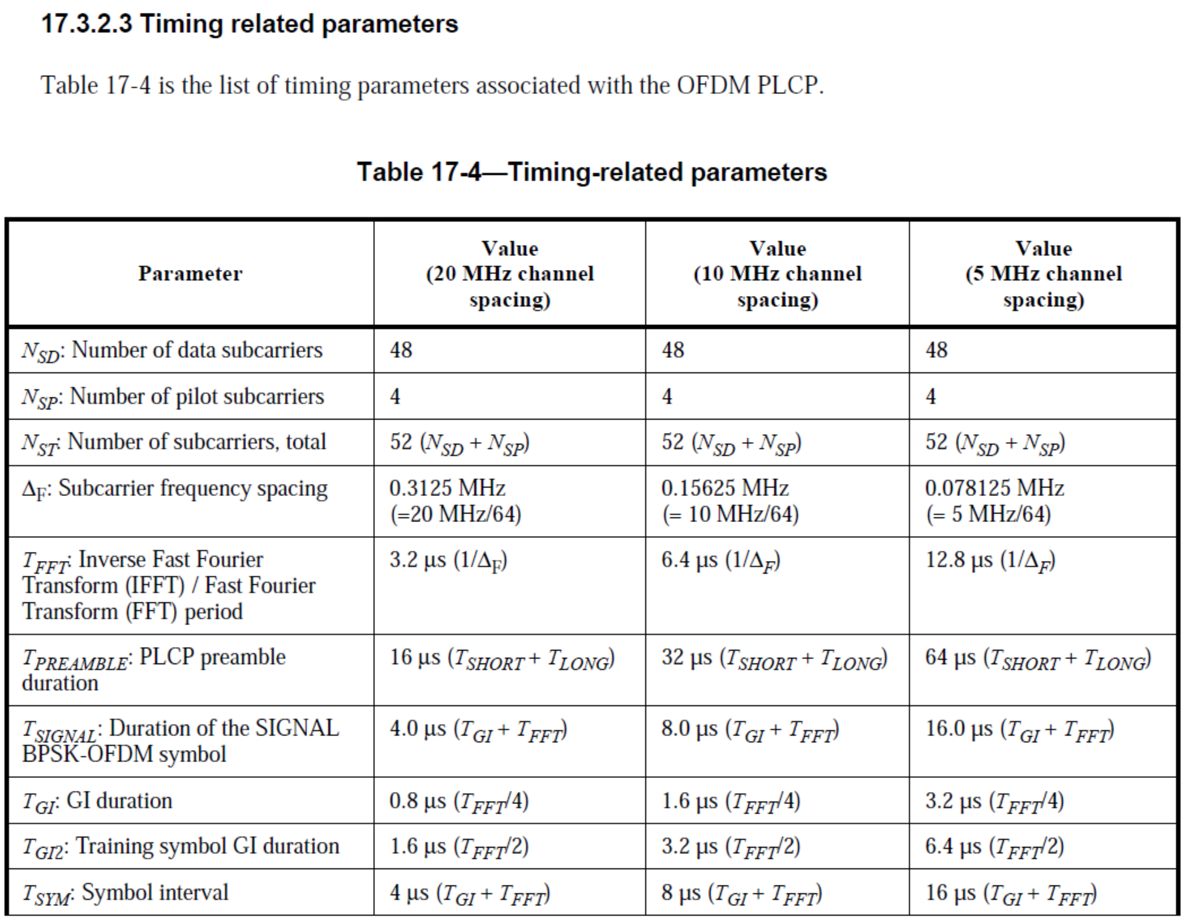
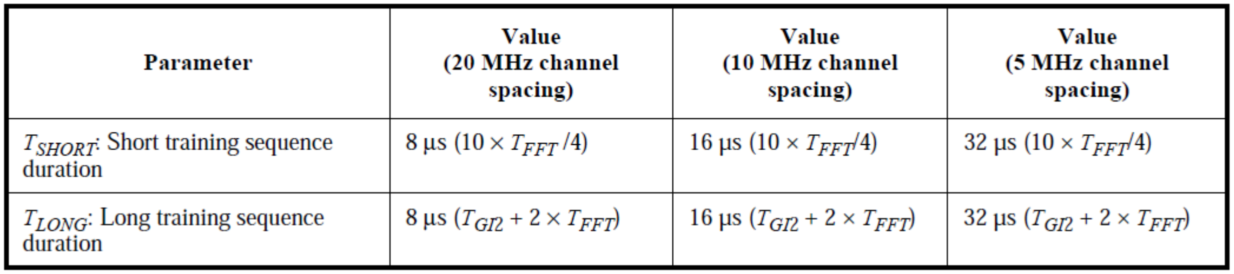
	

17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

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	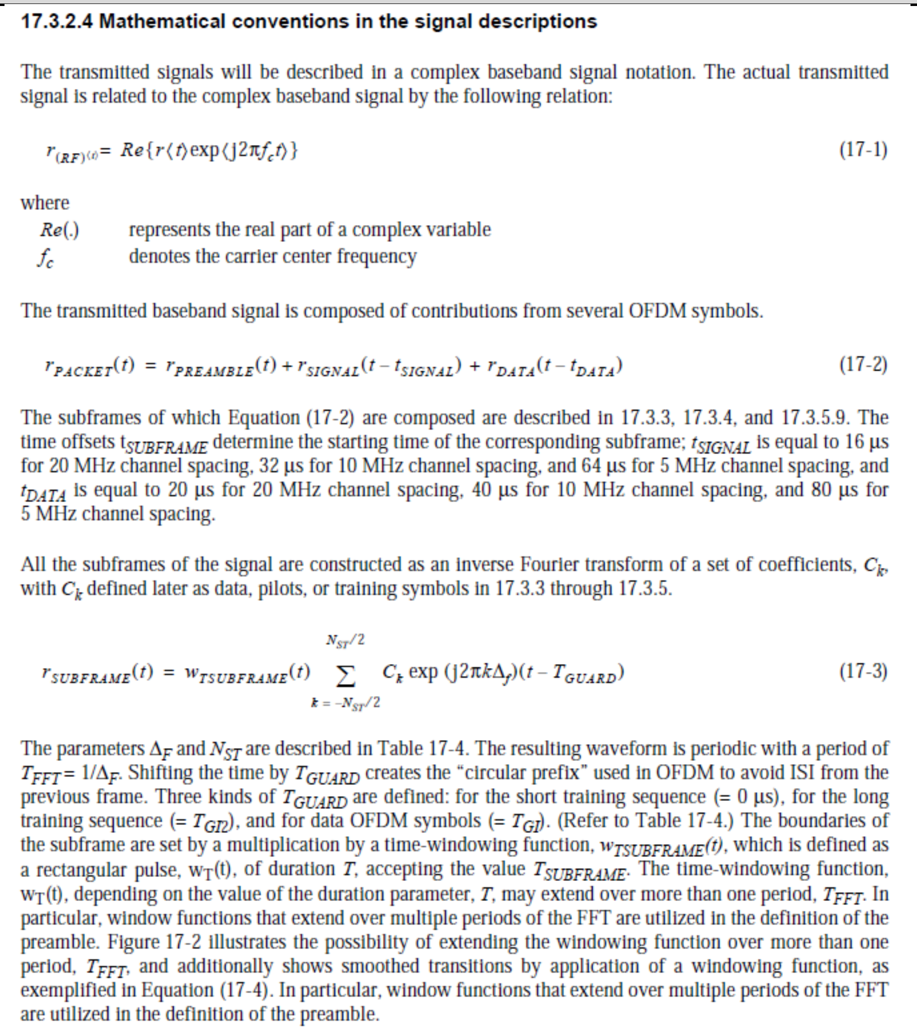 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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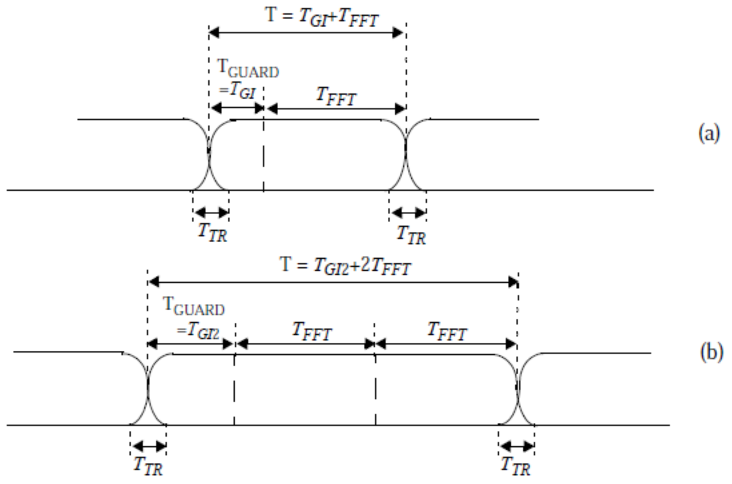
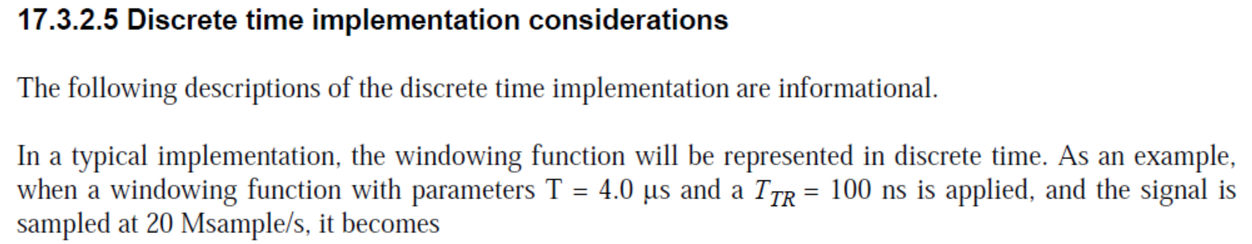
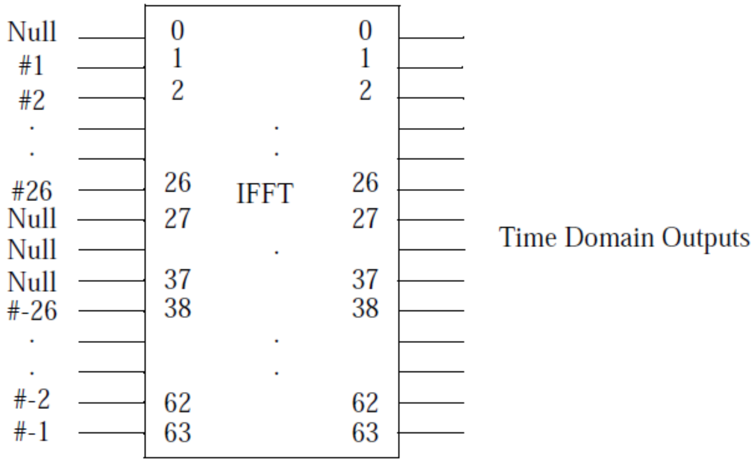
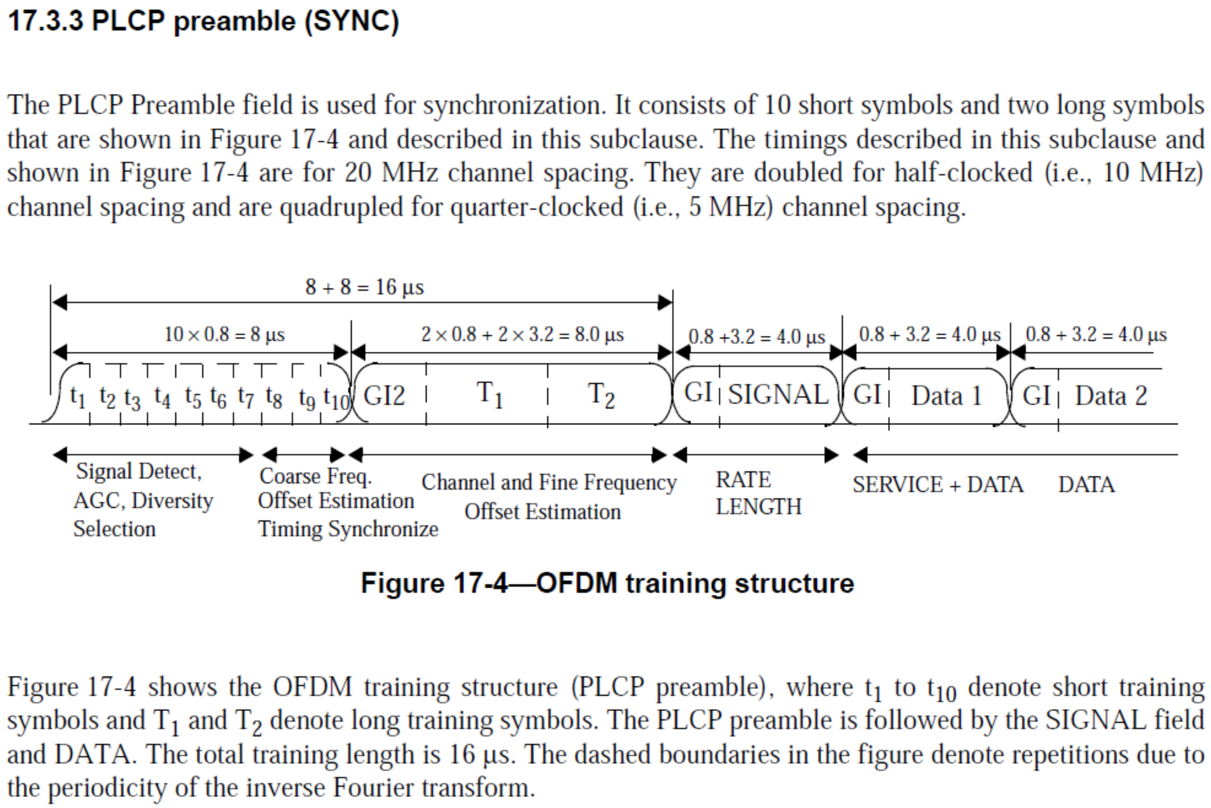
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ (17-4) In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{\begin{matrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{matrix}\right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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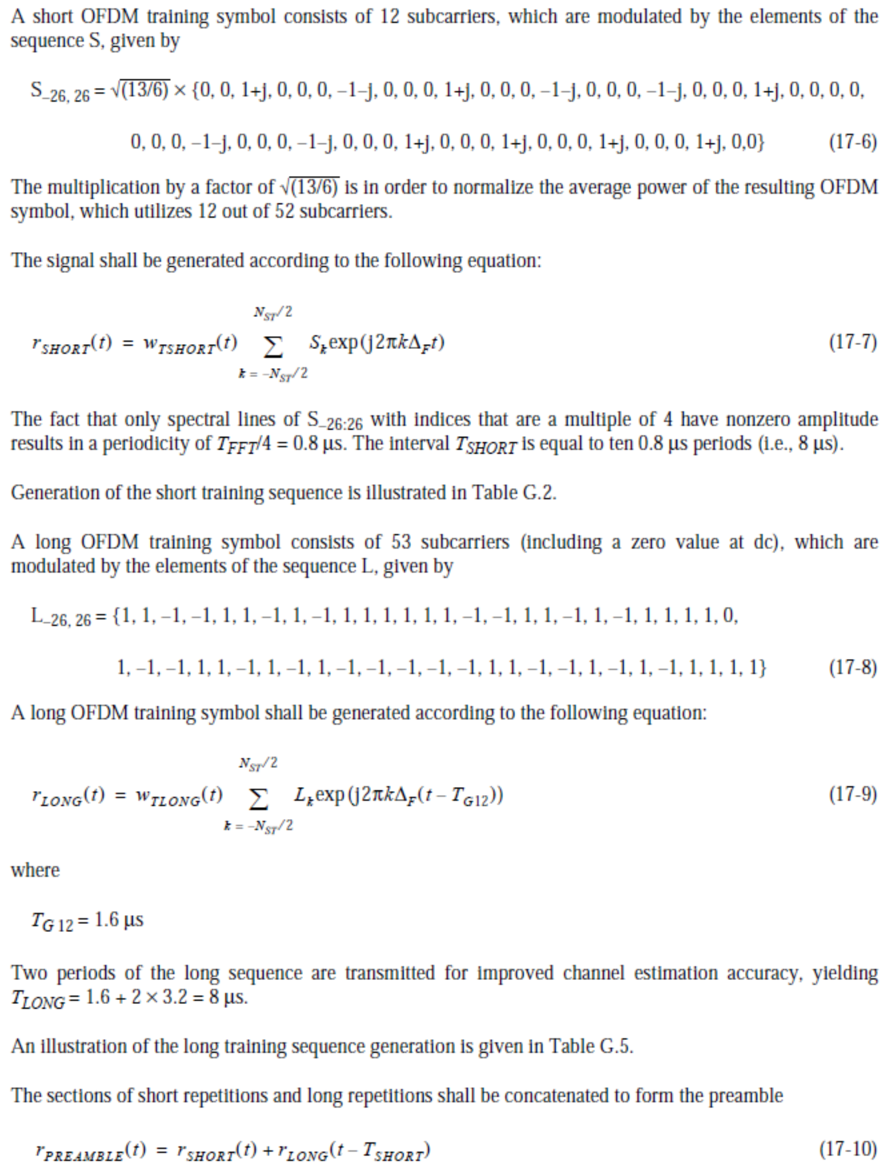
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

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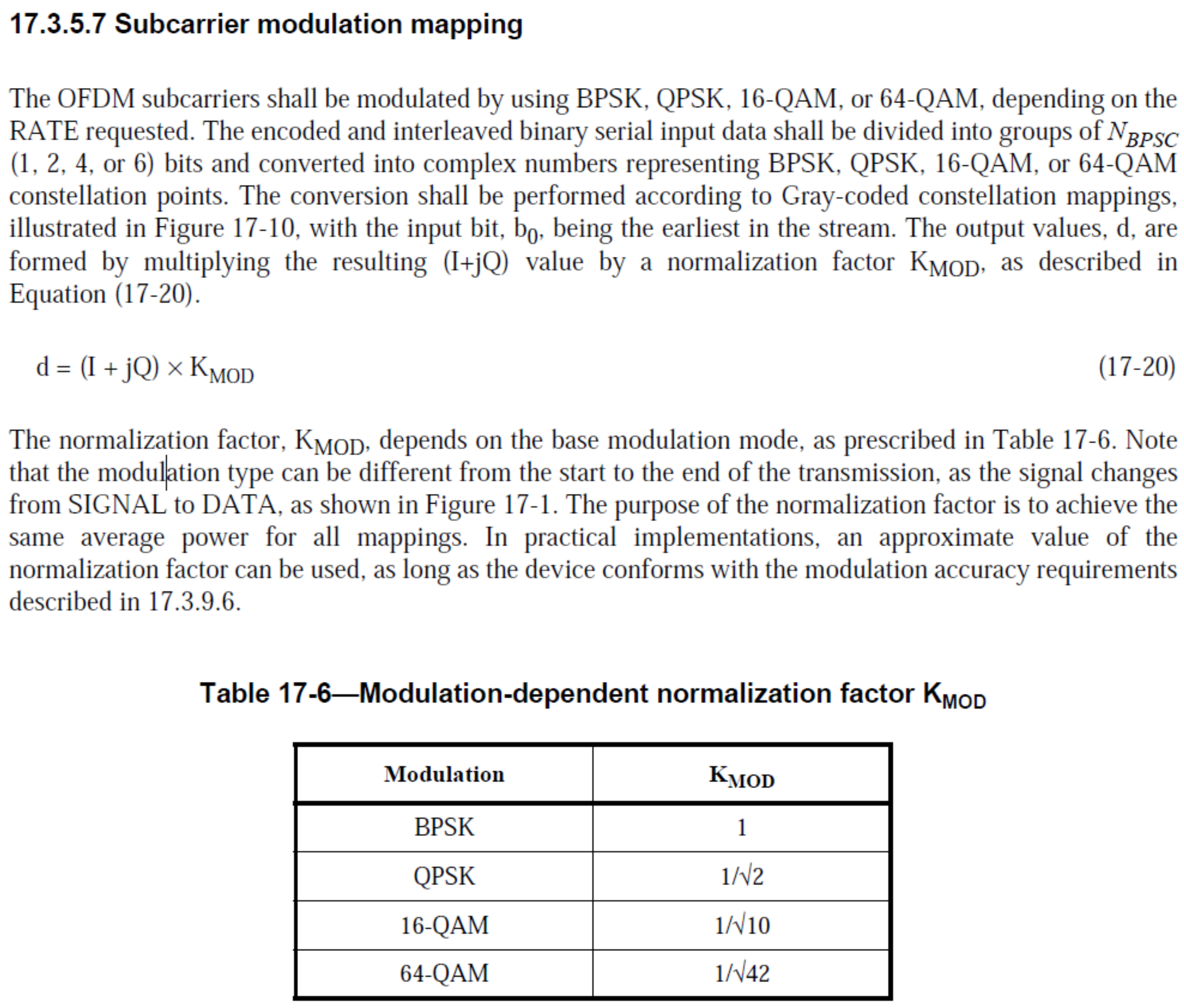
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

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</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \qquad (17\text{-}21)$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \qquad (17\text{-}22)$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \qquad (17\text{-}23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,\,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \qquad (17\text{-}24)$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

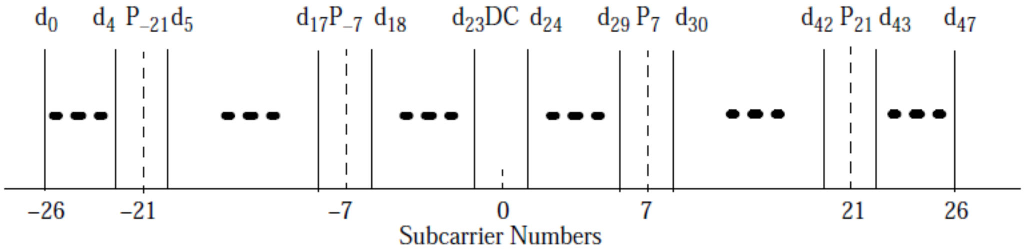


Figure 17-11—Subcarrier frequency allocation

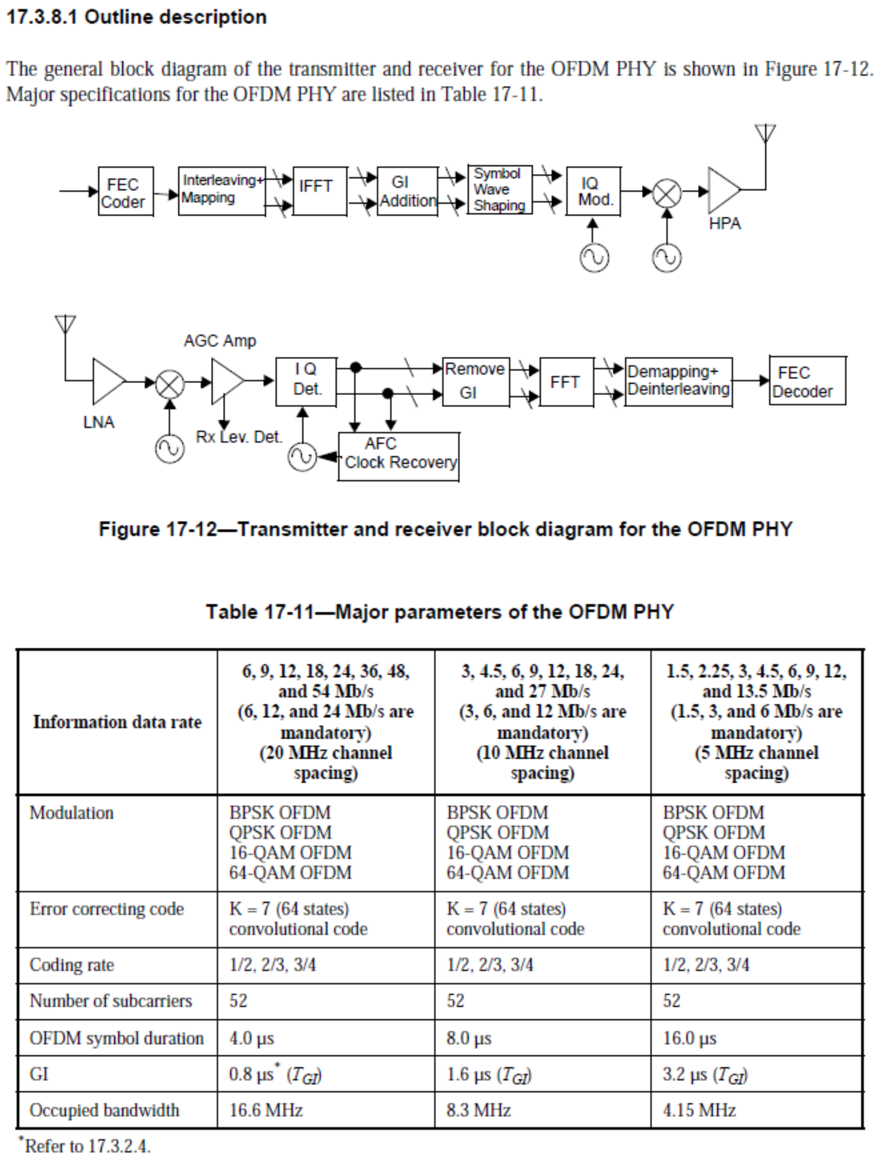
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

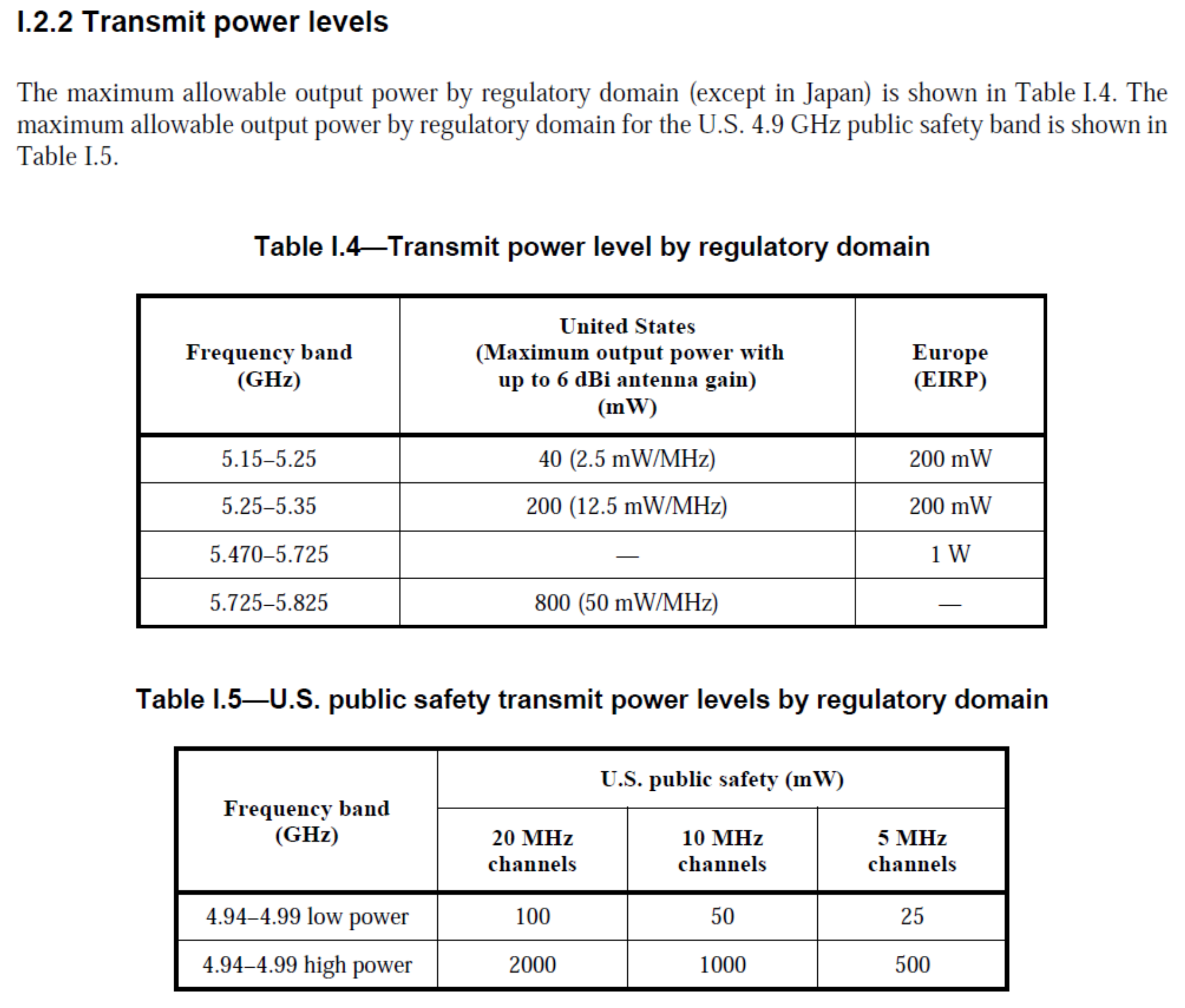
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs[*] (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

[*] Refer to 17.3.2.4.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

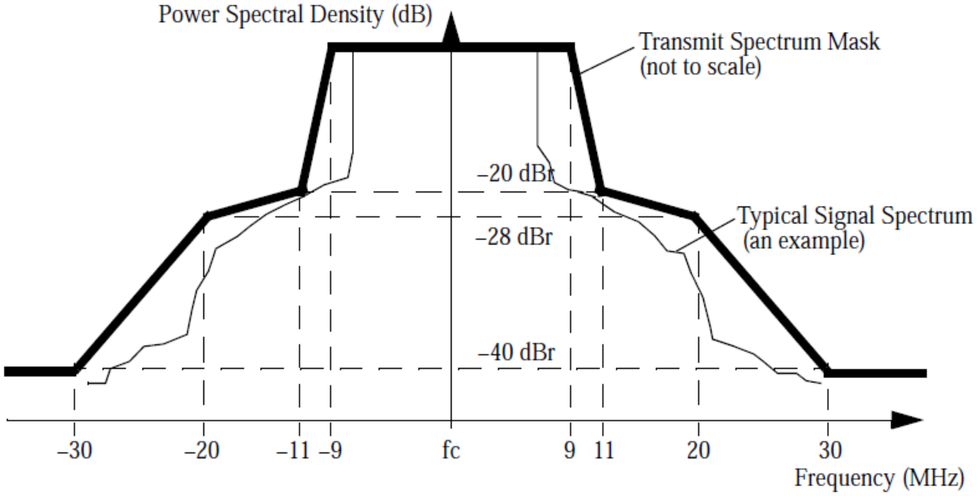
Table I.4—Transmit power level by regulatory domain

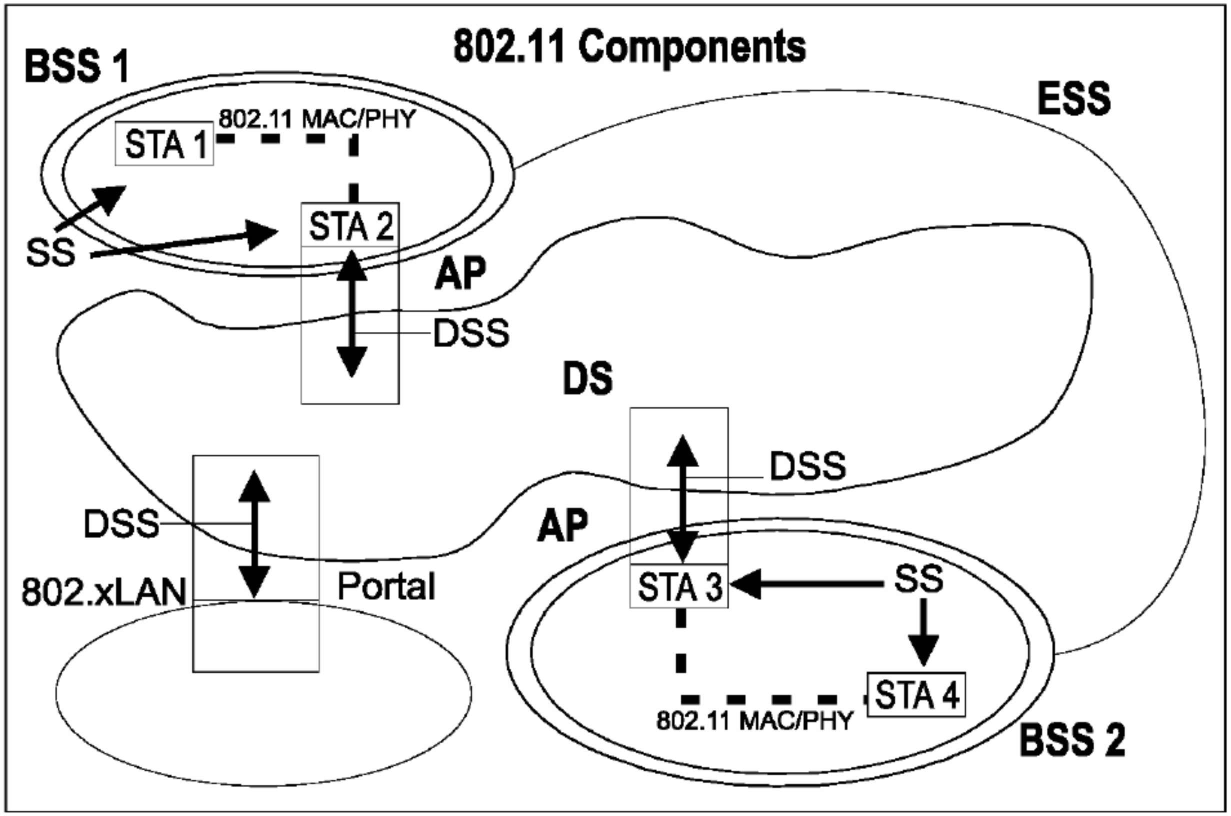
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

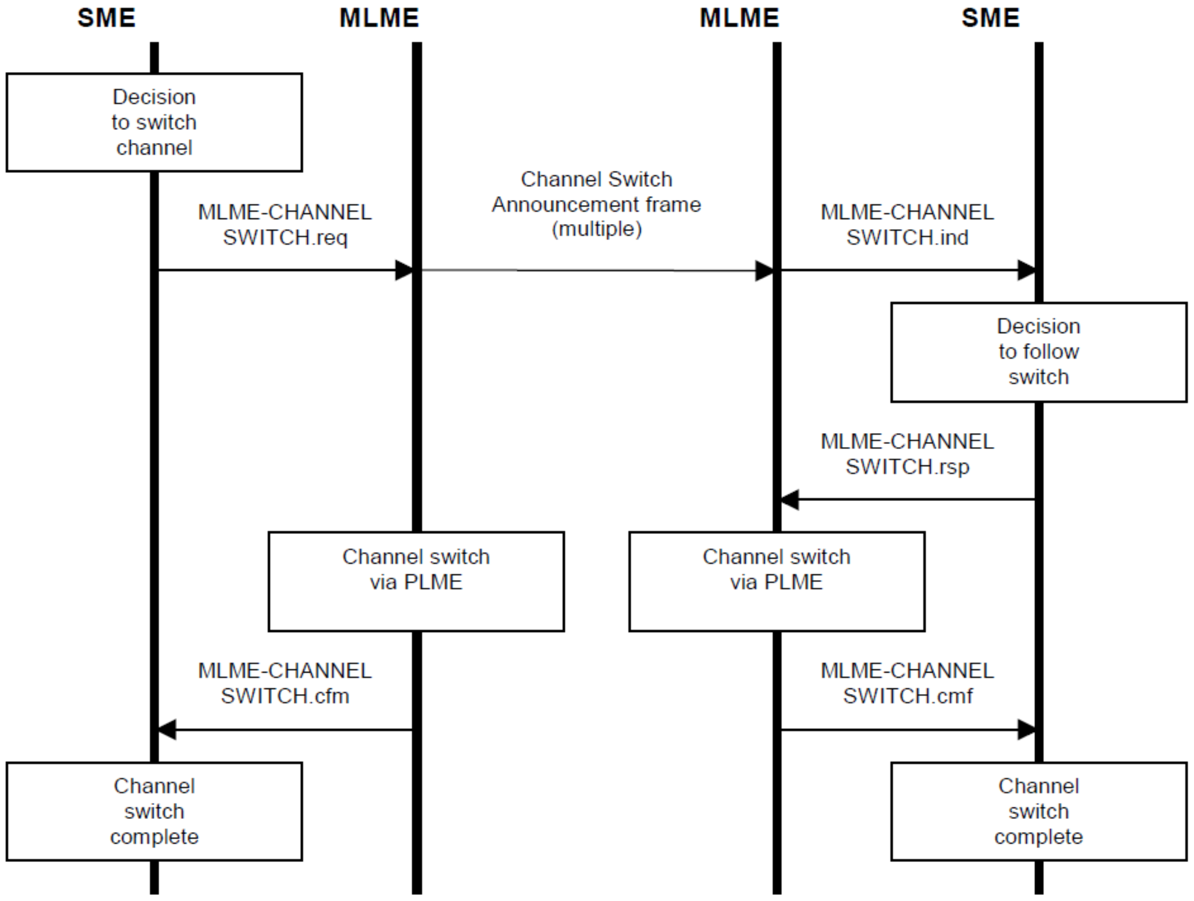
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

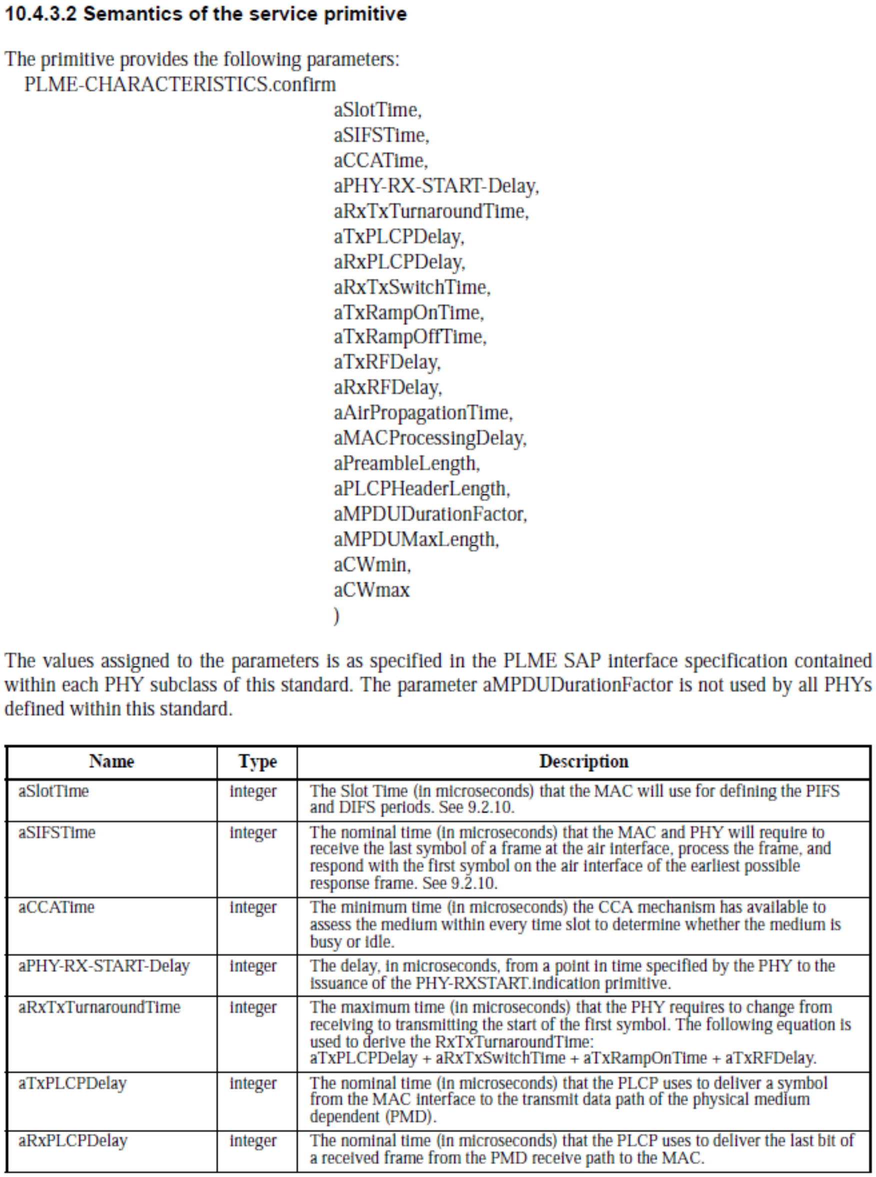
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.8] combining the first up-converted analog signal and the second up-converted analog signal to produce a combined up-converted signal;	802.11-2007 discloses “combining the first up-converted analog signal and the second up-converted analog signal to produce a combined up-converted signal.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

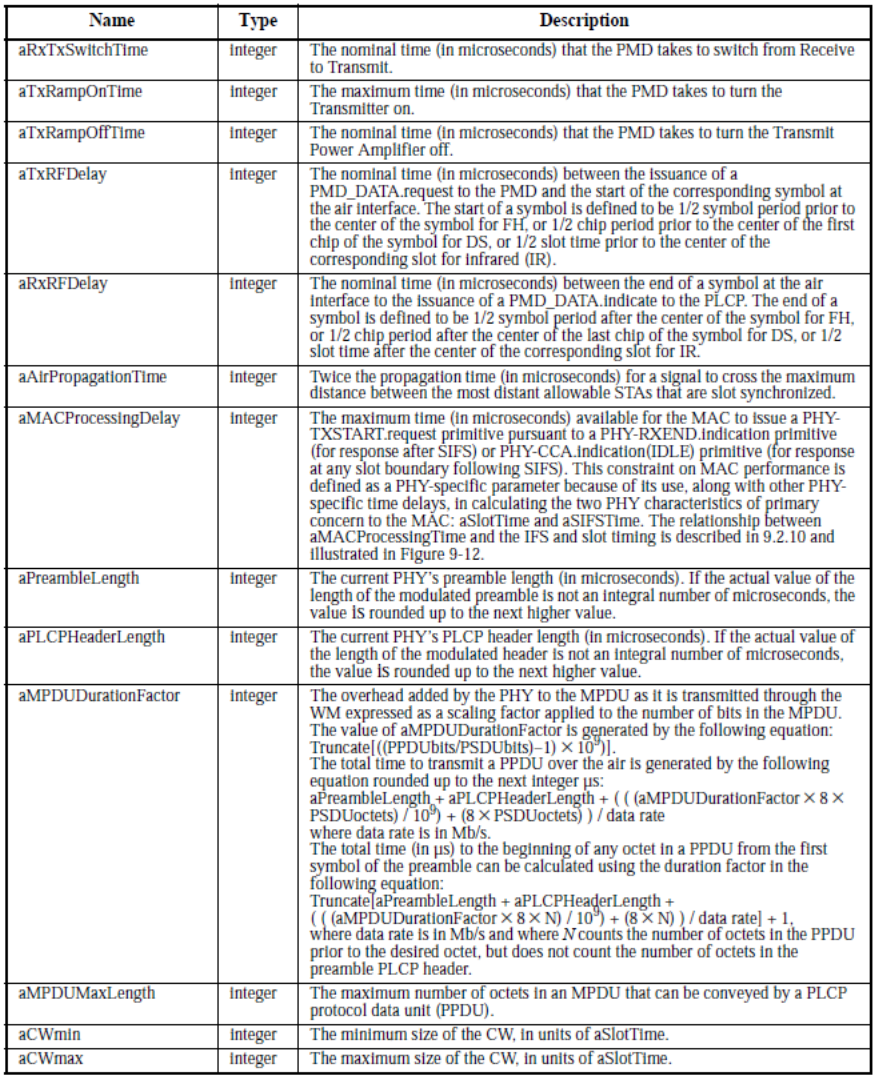
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007

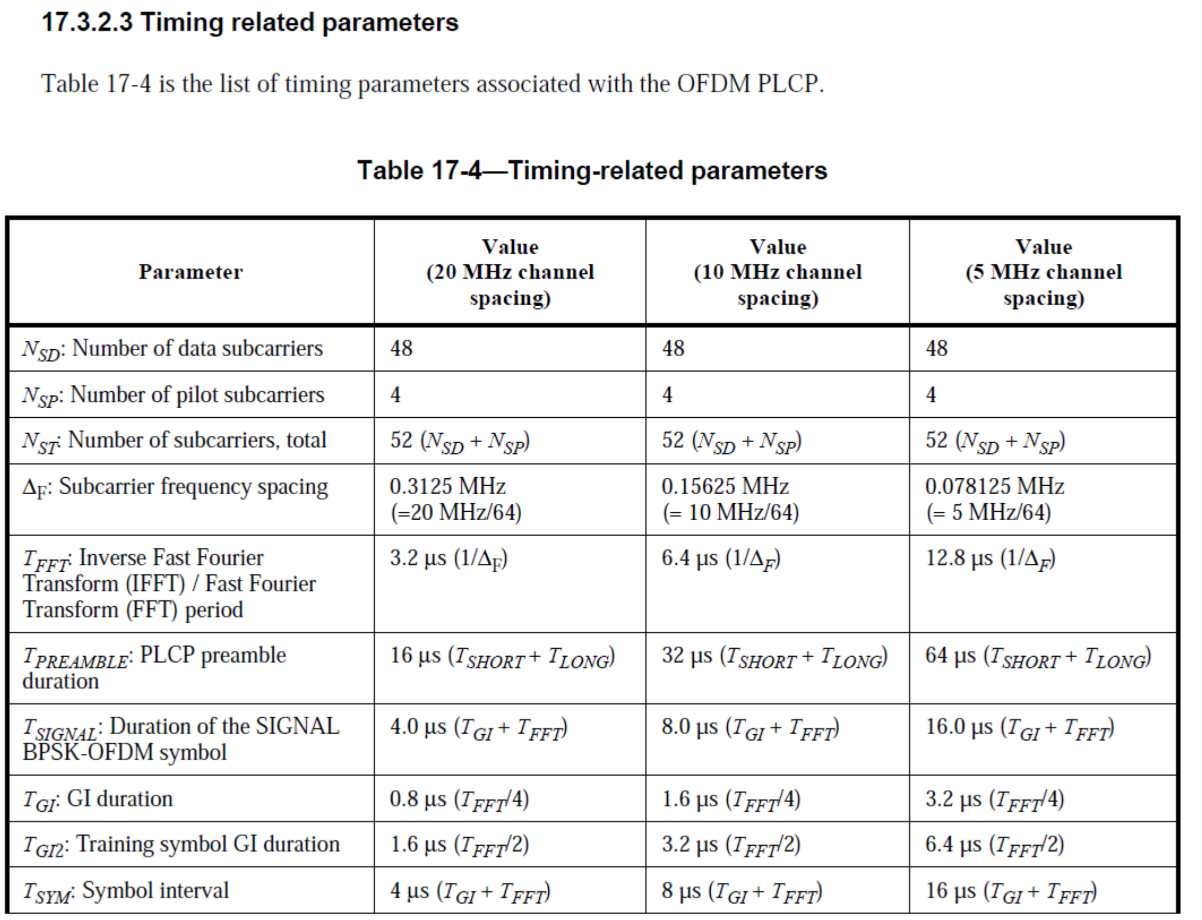


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

Claim 10 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

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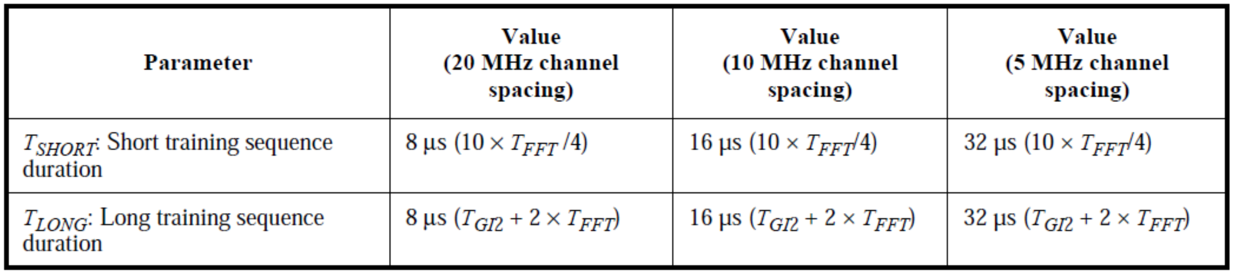
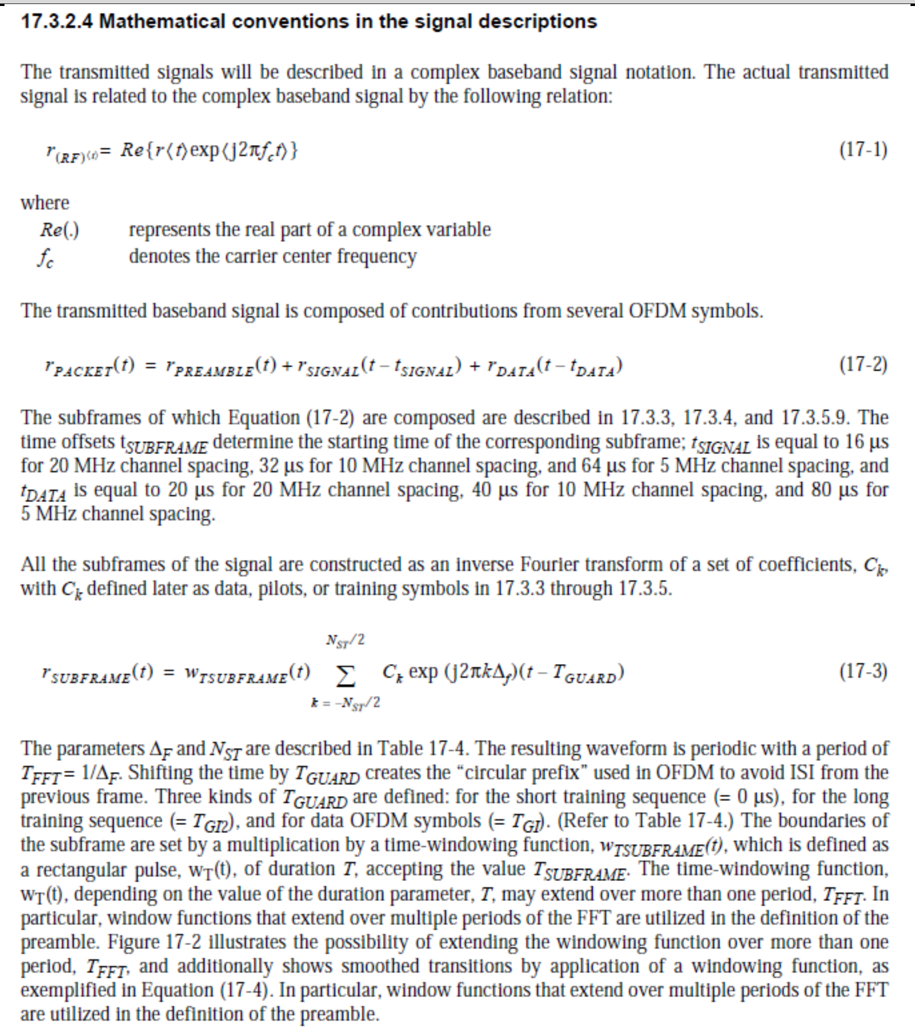

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)(t)} = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

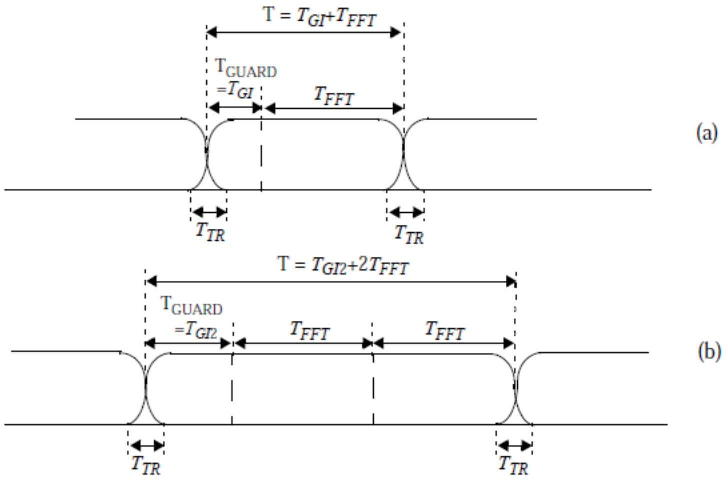
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

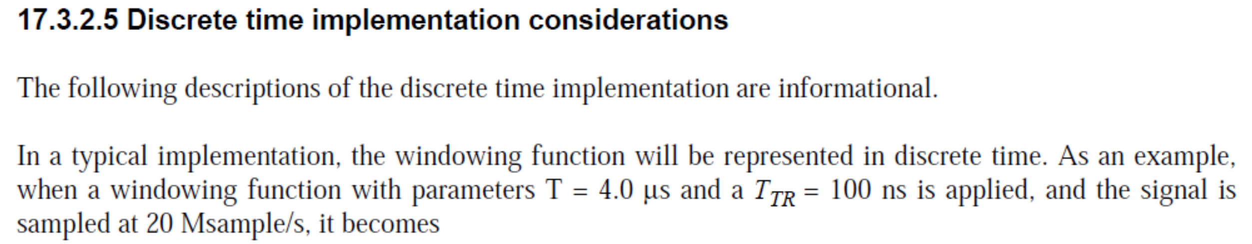
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

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<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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$$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\} \tag{17-5}$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

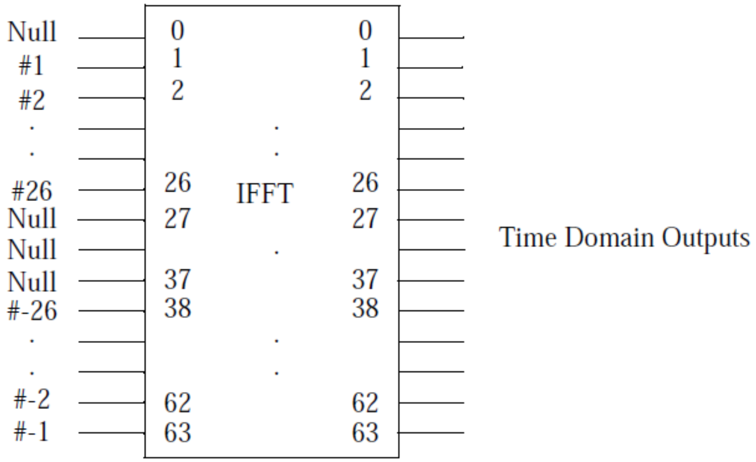
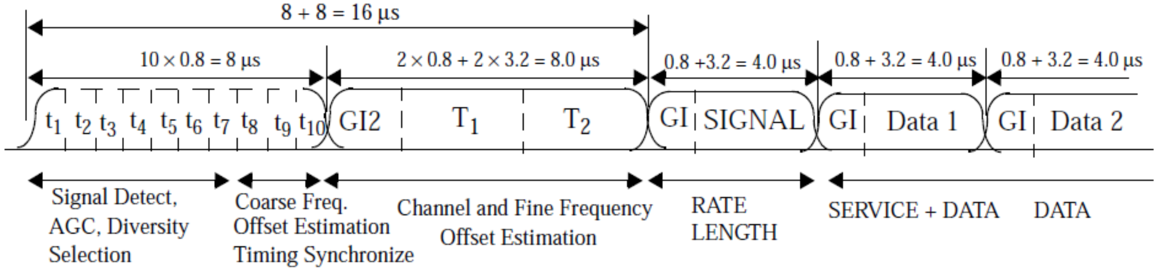
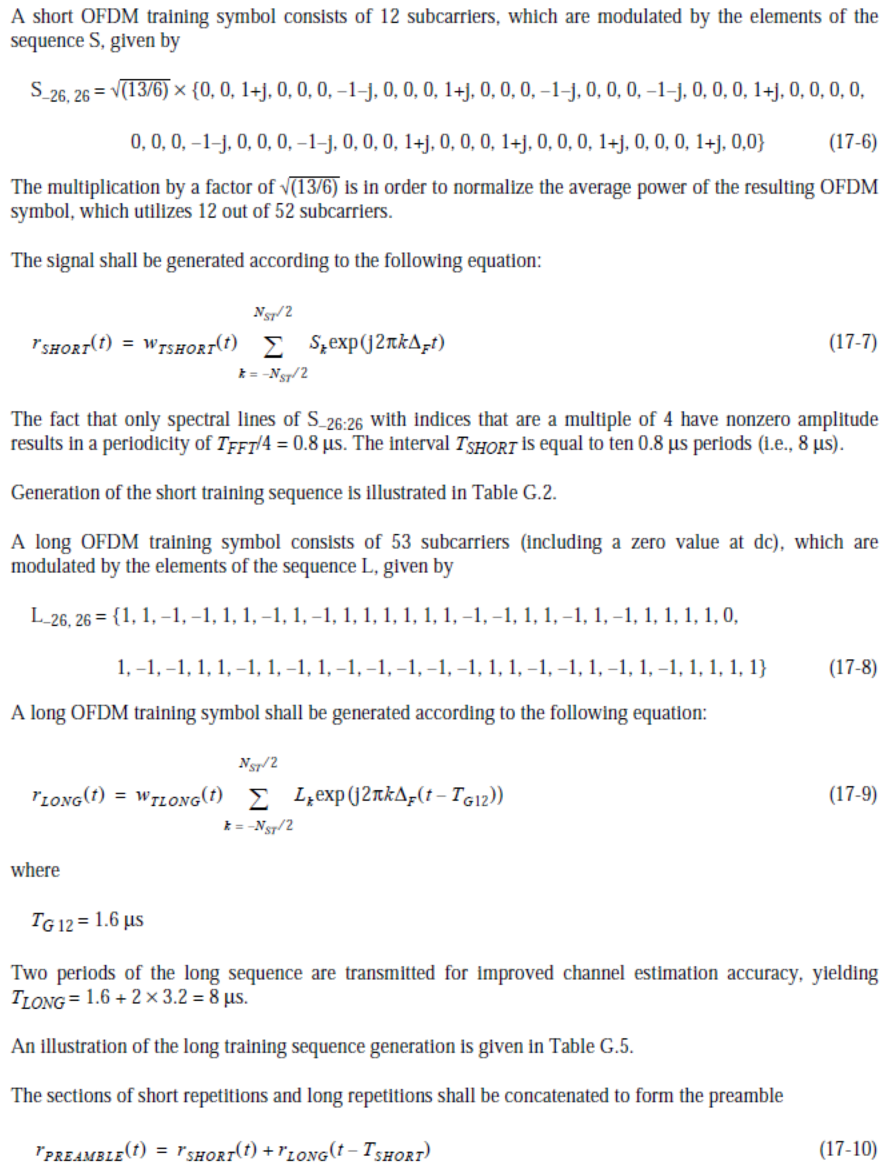


Figure 17-3—Inputs and outputs of inverse Fourier transform

See, e.g., 802.11-2007 § 17.3.2.5

</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

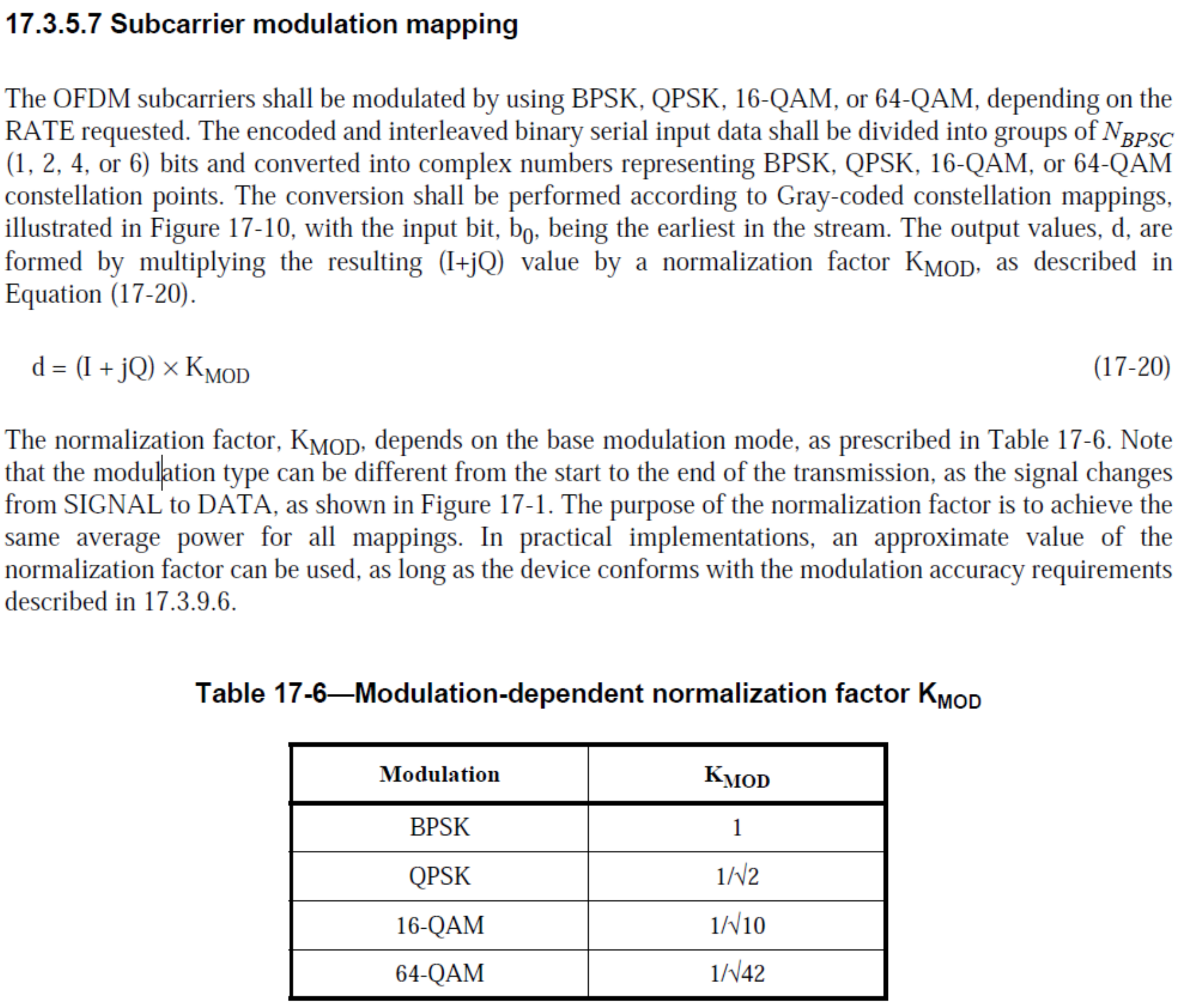
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}\,, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

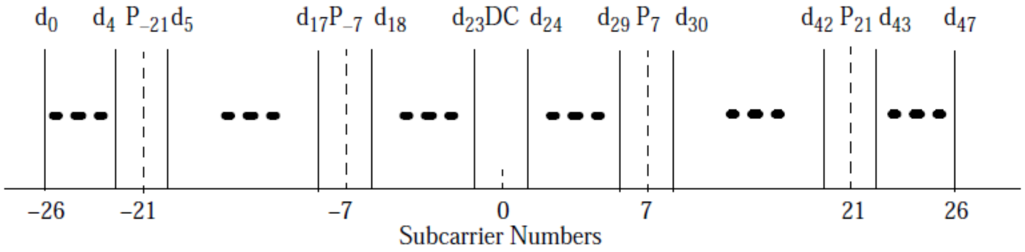


Figure 17-11—Subcarrier frequency allocation

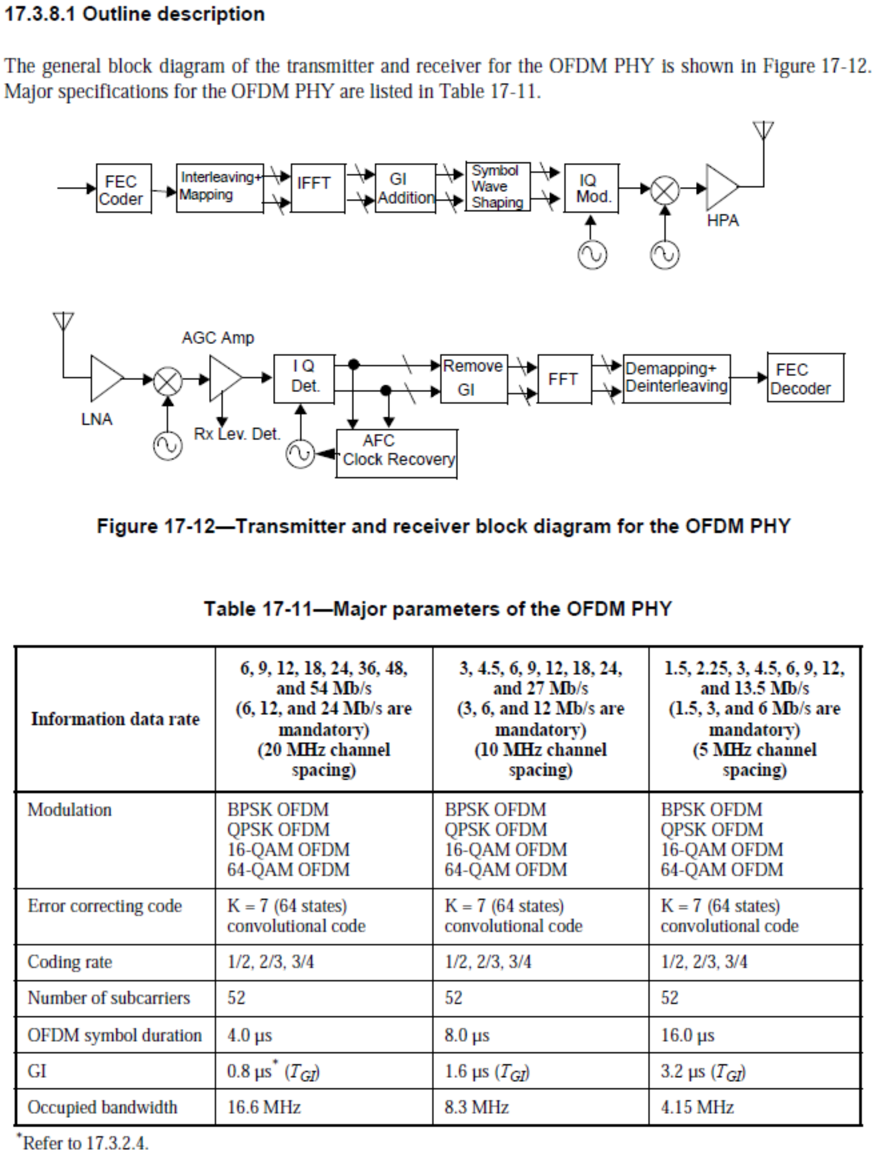
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

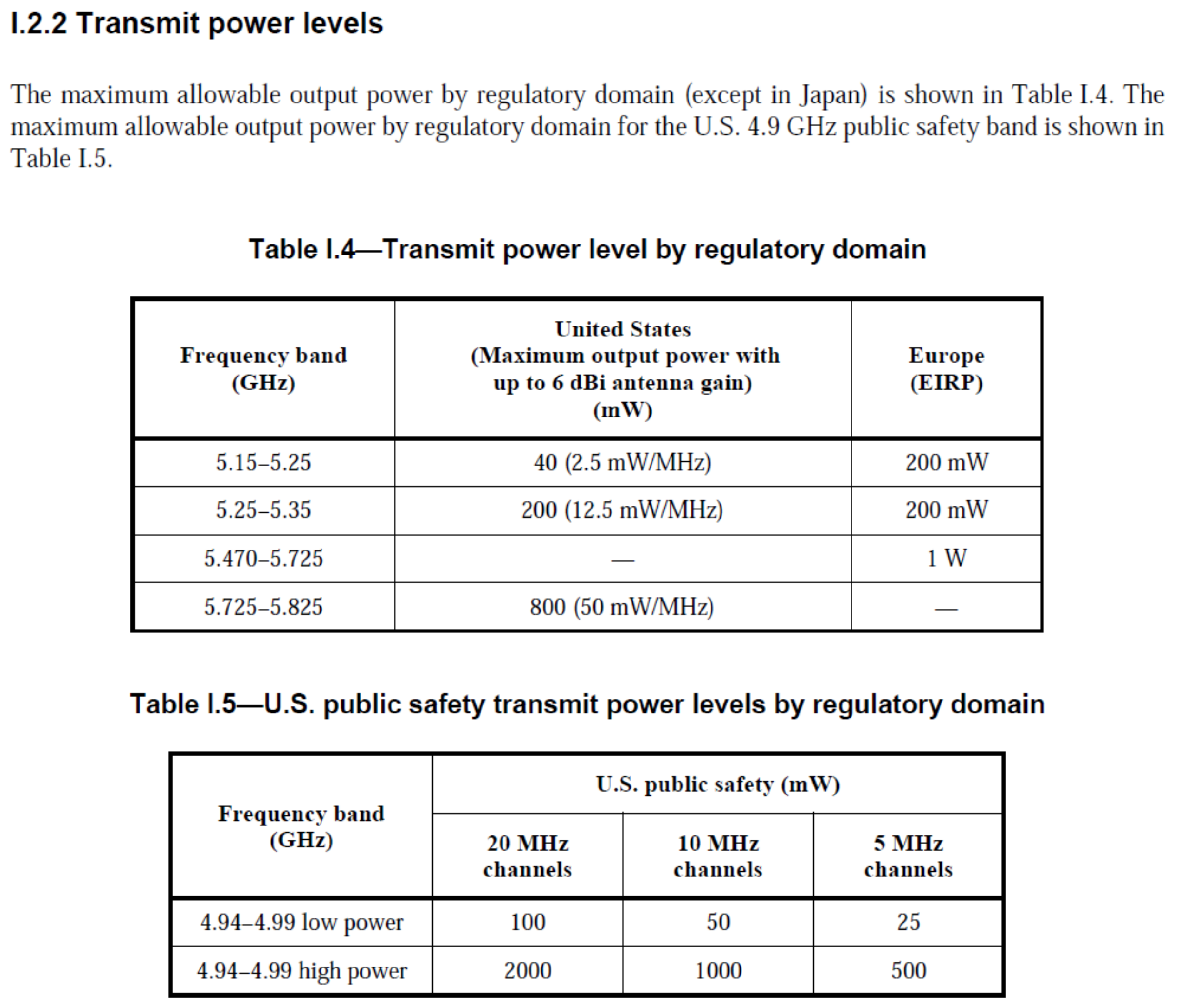
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

Table I.4—Transmit power level by regulatory domain

<table>
<tr><th>Frequency band (GHz)</th><th>United States (Maximum output power with up to 6 dBi antenna gain) (mW)</th><th>Europe (EIRP)</th></tr>
<tr><td>5.15–5.25</td><td>40 (2.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.25–5.35</td><td>200 (12.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.470–5.725</td><td>—</td><td>1 W</td></tr>
<tr><td>5.725–5.825</td><td>800 (50 mW/MHz)</td><td>—</td></tr>
</table>

Table I.5—U.S. public safety transmit power levels by regulatory domain

<table>
<tr><th rowspan="2">Frequency band (GHz)</th><th colspan="3">U.S. public safety (mW)</th></tr>
<tr><th>20 MHz channels</th><th>10 MHz channels</th><th>5 MHz channels</th></tr>
<tr><td>4.94–4.99 low power</td><td>100</td><td>50</td><td>25</td></tr>
<tr><td>4.94–4.99 high power</td><td>2000</td><td>1000</td><td>500</td></tr>
</table>

See, e.g., 802.11-2007 § I.2.2
</td></tr>
</table>

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

I.2.3 Transmit spectrum mask

For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

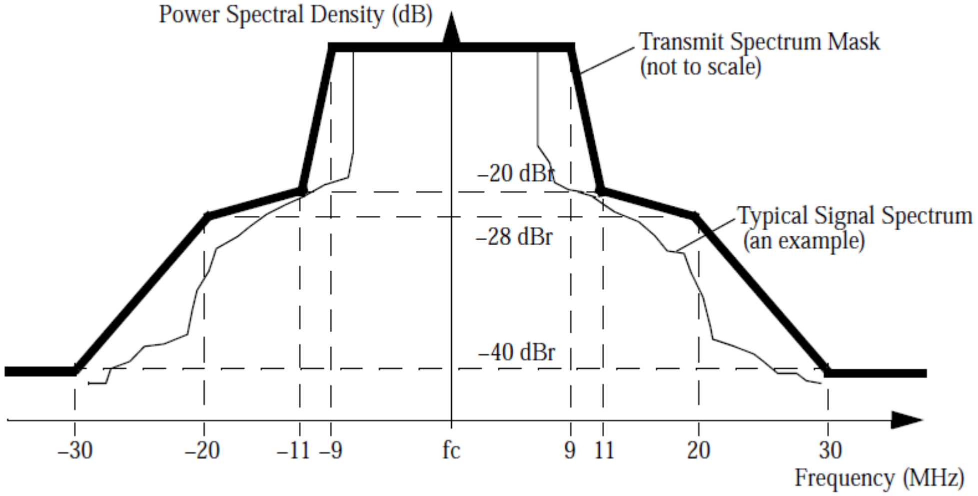
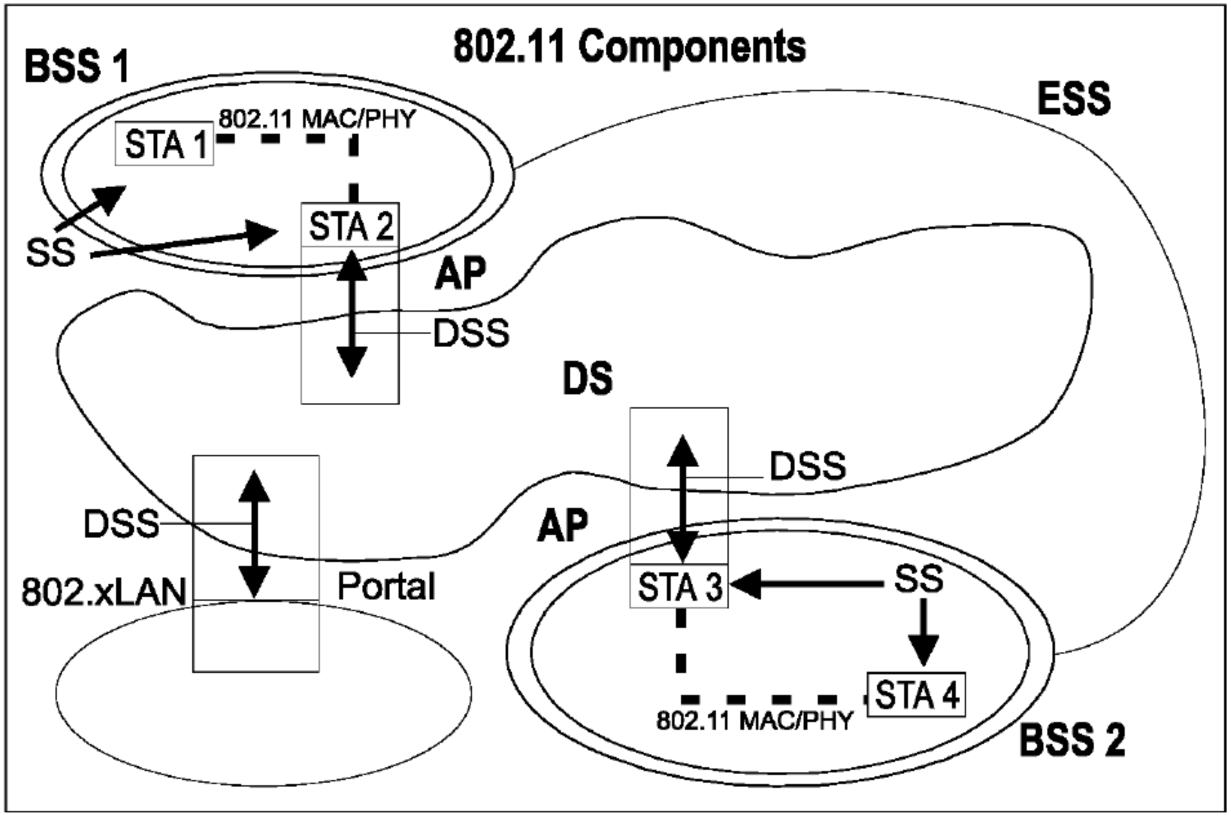
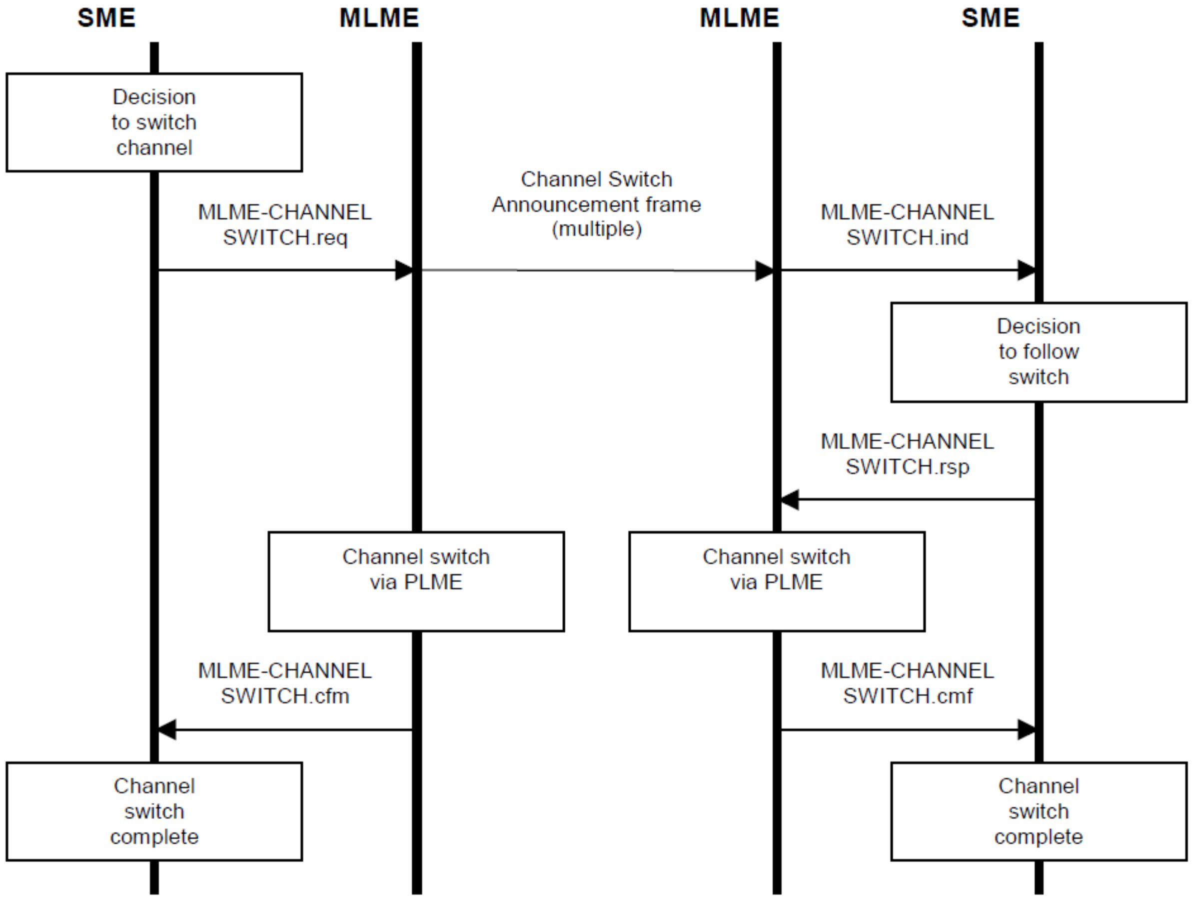


Figure I.1—Transmit spectrum mask

See, e.g., 802.11-2007 § I.2.3

</td></tr>
</table>

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 10 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.9] amplifying the combined up-converted signal in a power amplifier resulting in an amplified combined up-converted signal; and	802.11-2007 discloses "amplifying the combined up-converted signal in a power amplifier resulting in an amplified combined up-converted signal." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:
PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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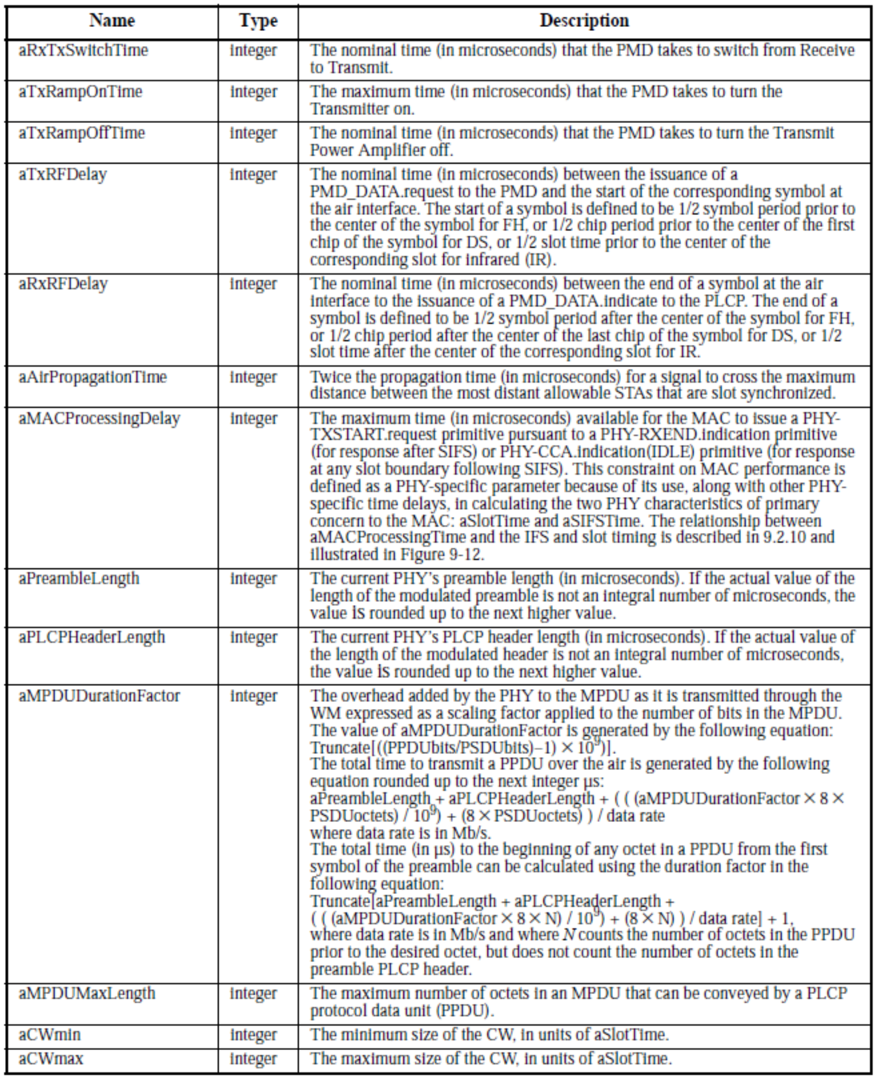

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\mathrm{Truncate}[((\mathrm{PPDUbits}/\mathrm{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times \mathrm{PSDUoctets}) / 10^9) + (8 \times \mathrm{PSDUoctets})) / \mathrm{data\ rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\mathrm{Truncate}[\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \mathrm{data\ rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5 .2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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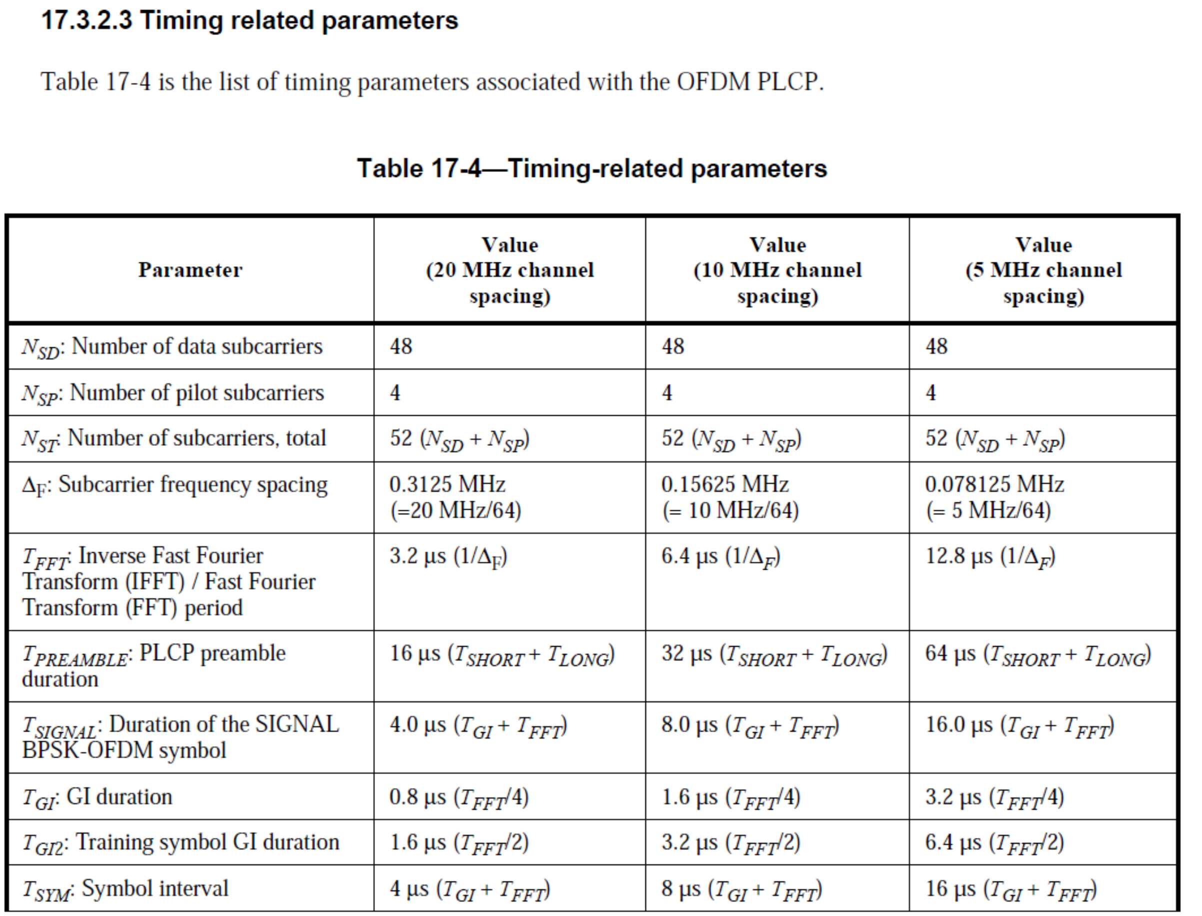
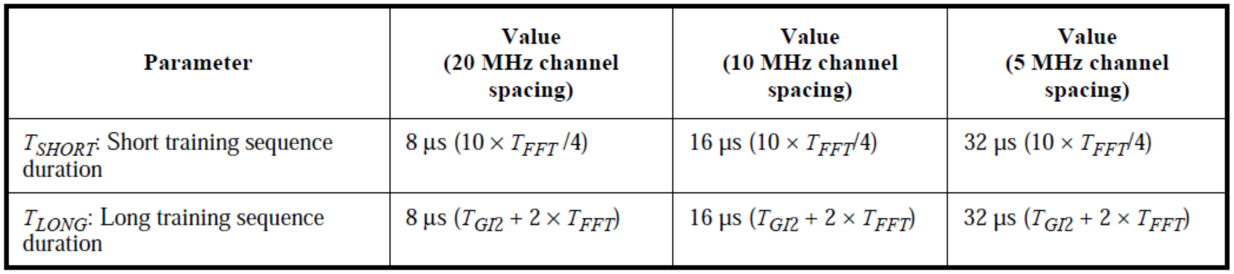
	

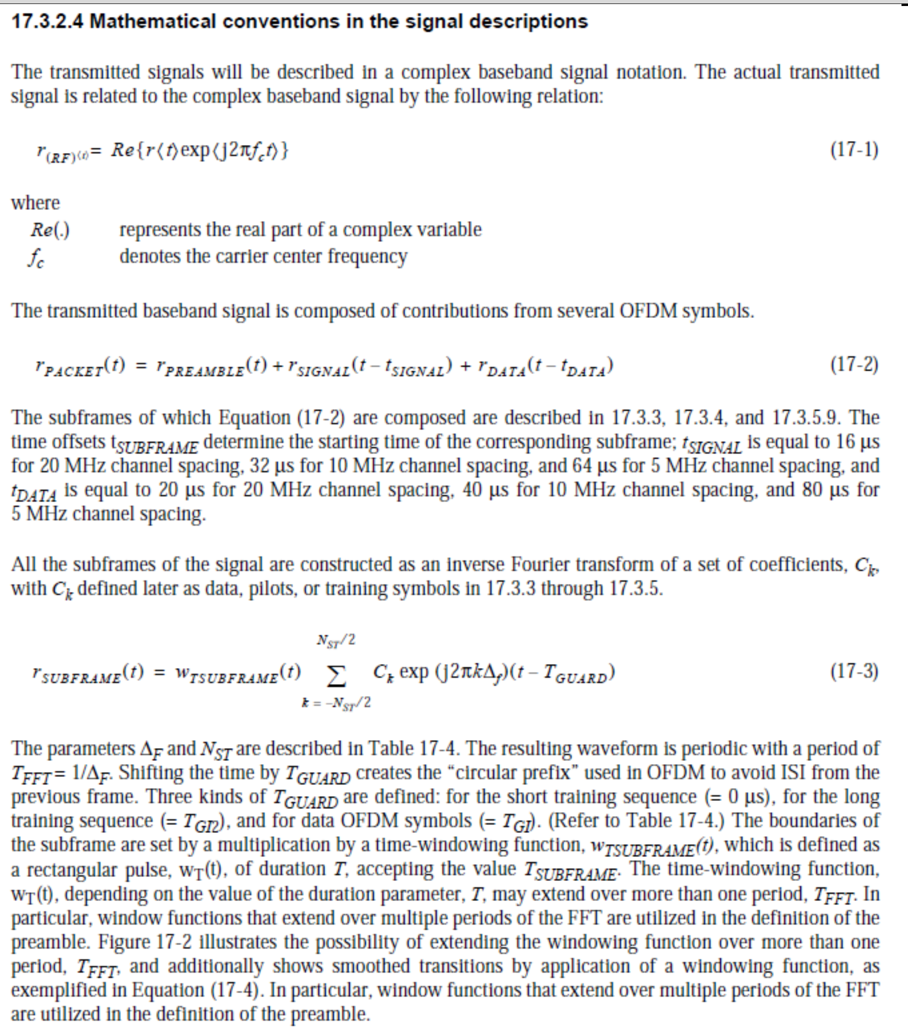
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

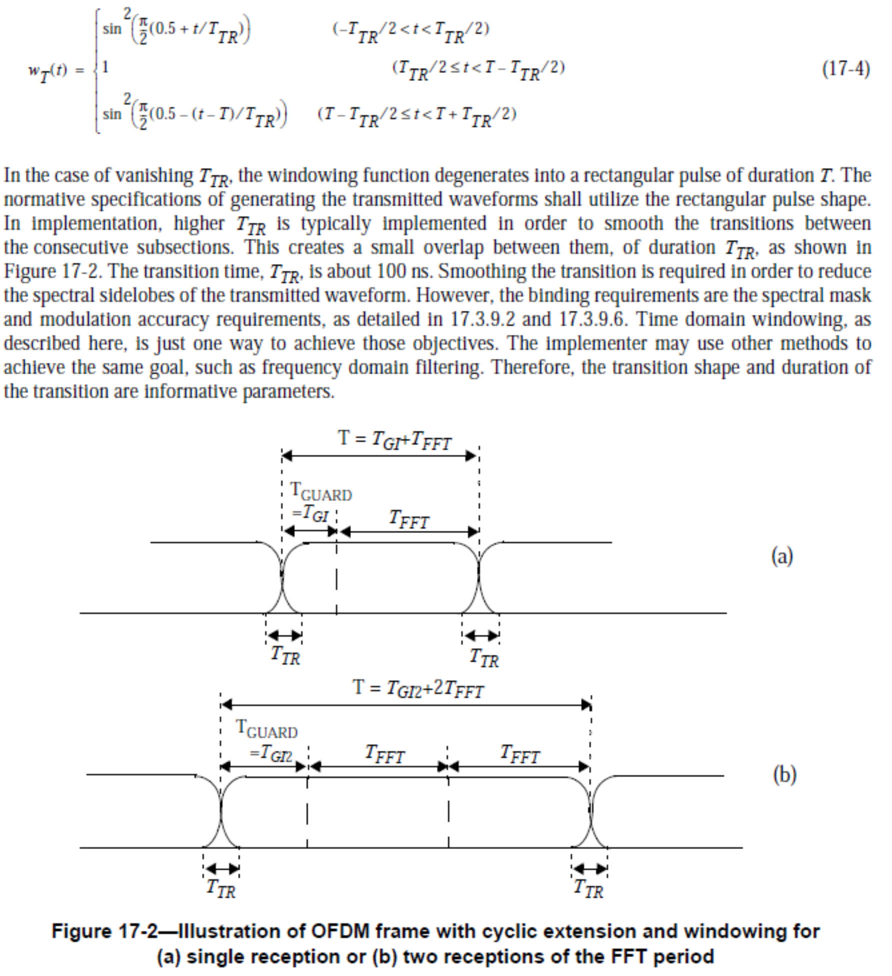
Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



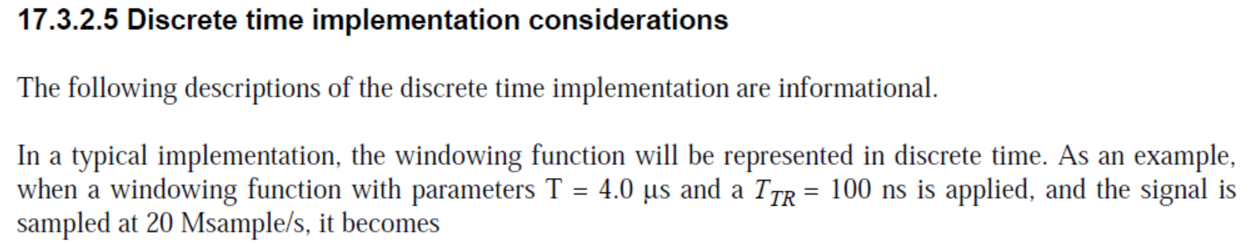
$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$$

In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.

Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period

See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

$$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\} \tag{17-5}$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

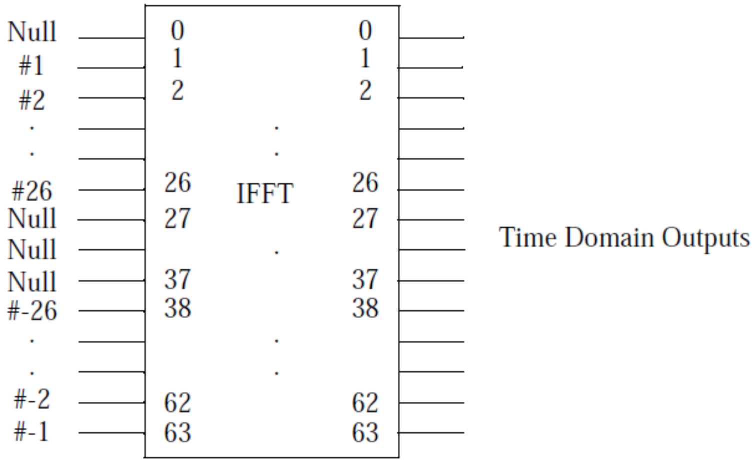
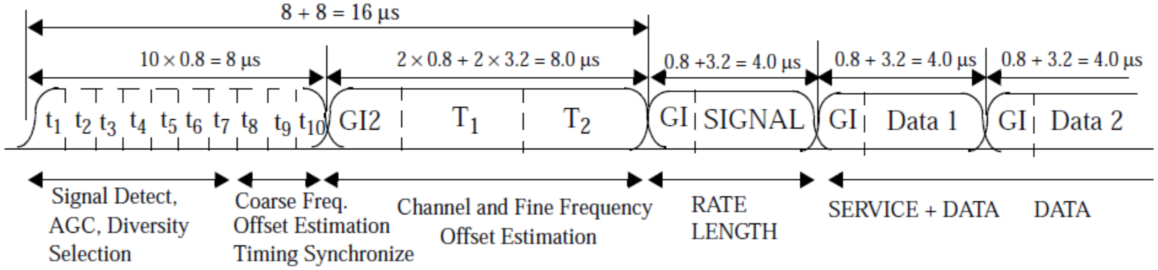
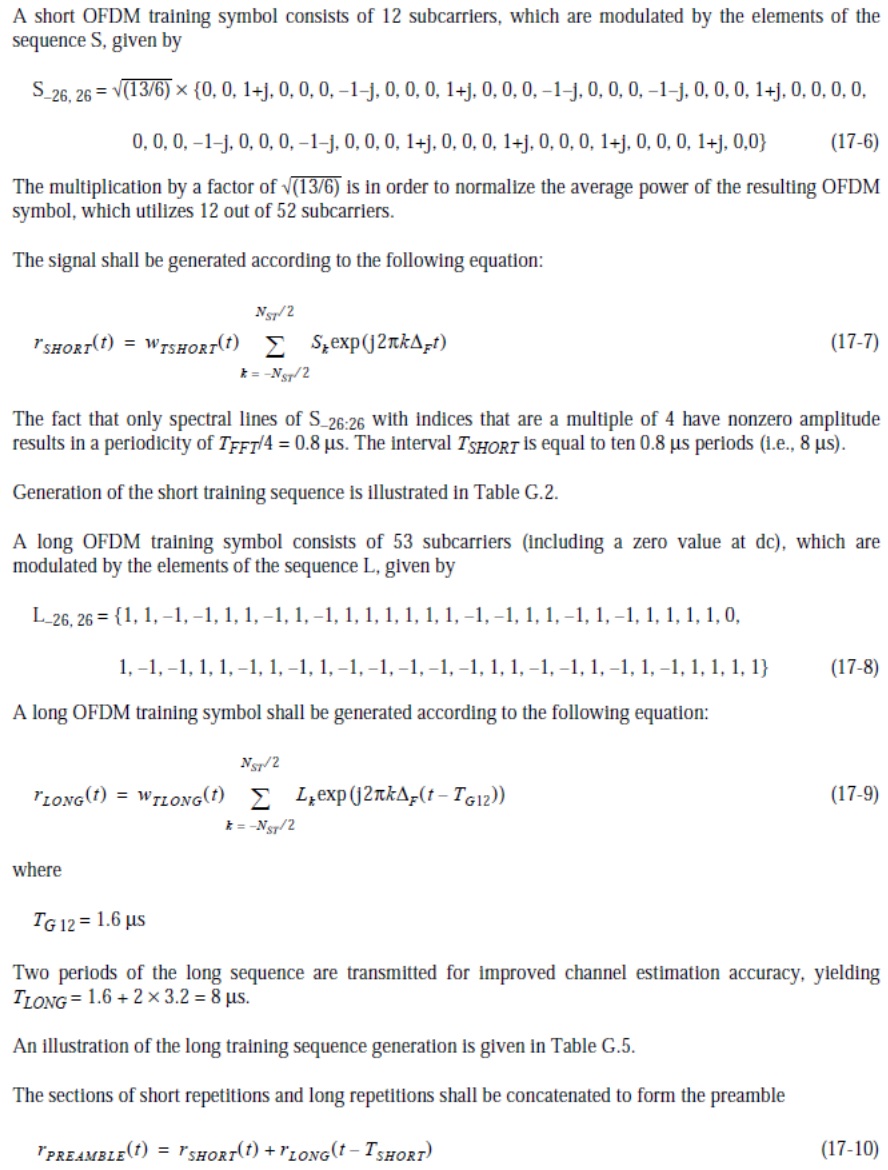


Figure 17-3—Inputs and outputs of inverse Fourier transform

See, e.g., 802.11-2007 § 17.3.2.5

</td></tr>
</table>

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

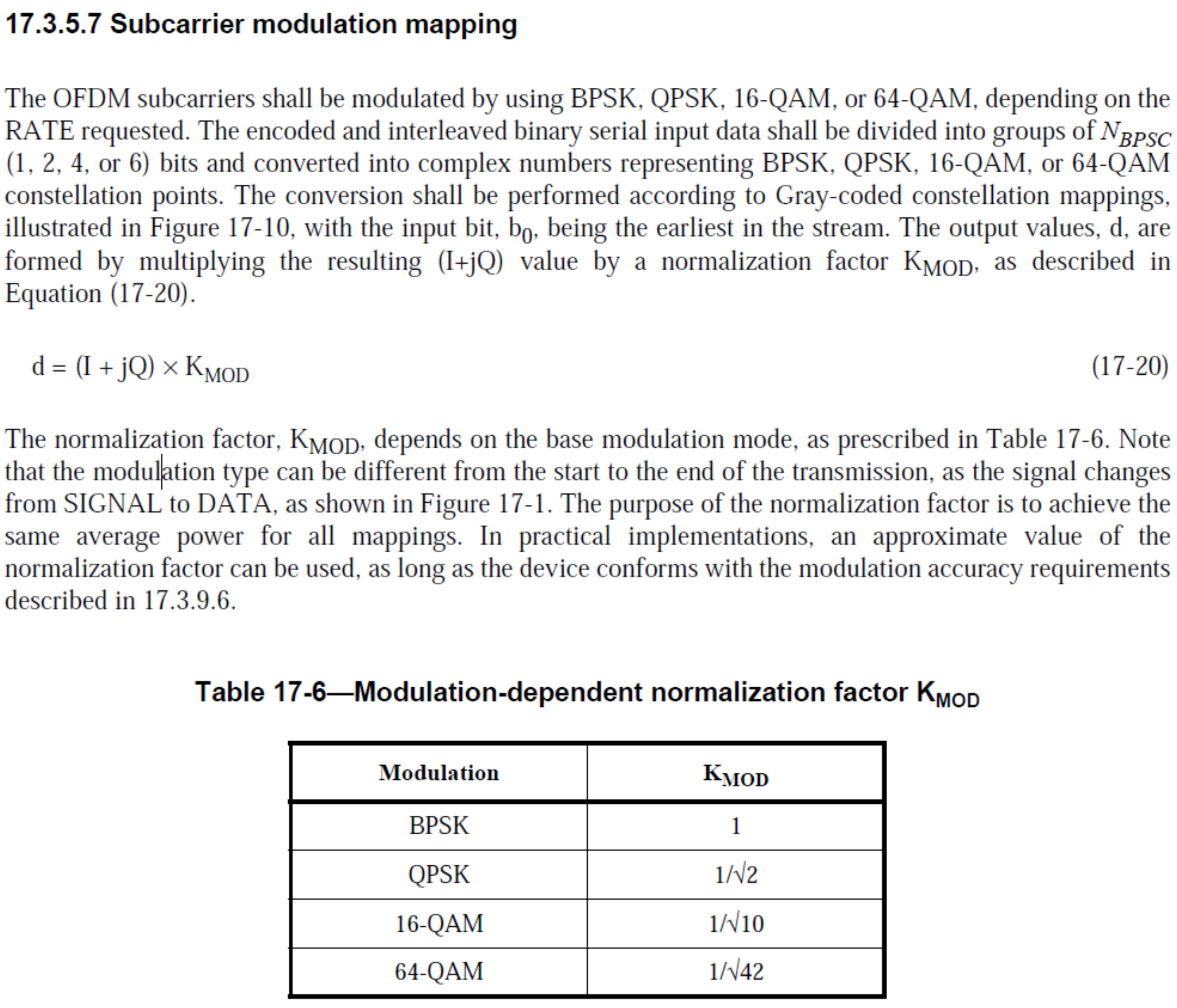
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k + N_{SD} \times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n} \exp\left((j2\pi M(k)\Delta_F(t - T_{GI})\right) + p_{n+1} \sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

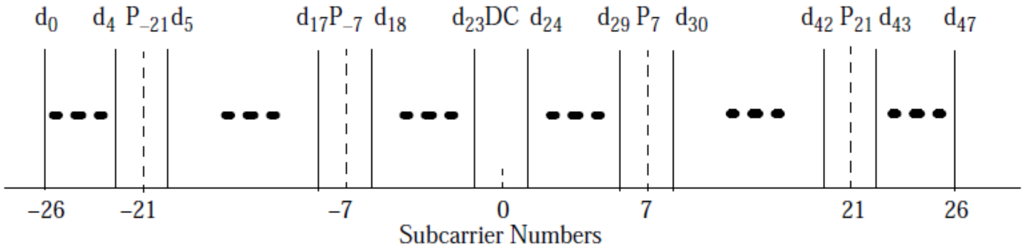


Figure 17-11—Subcarrier frequency allocation

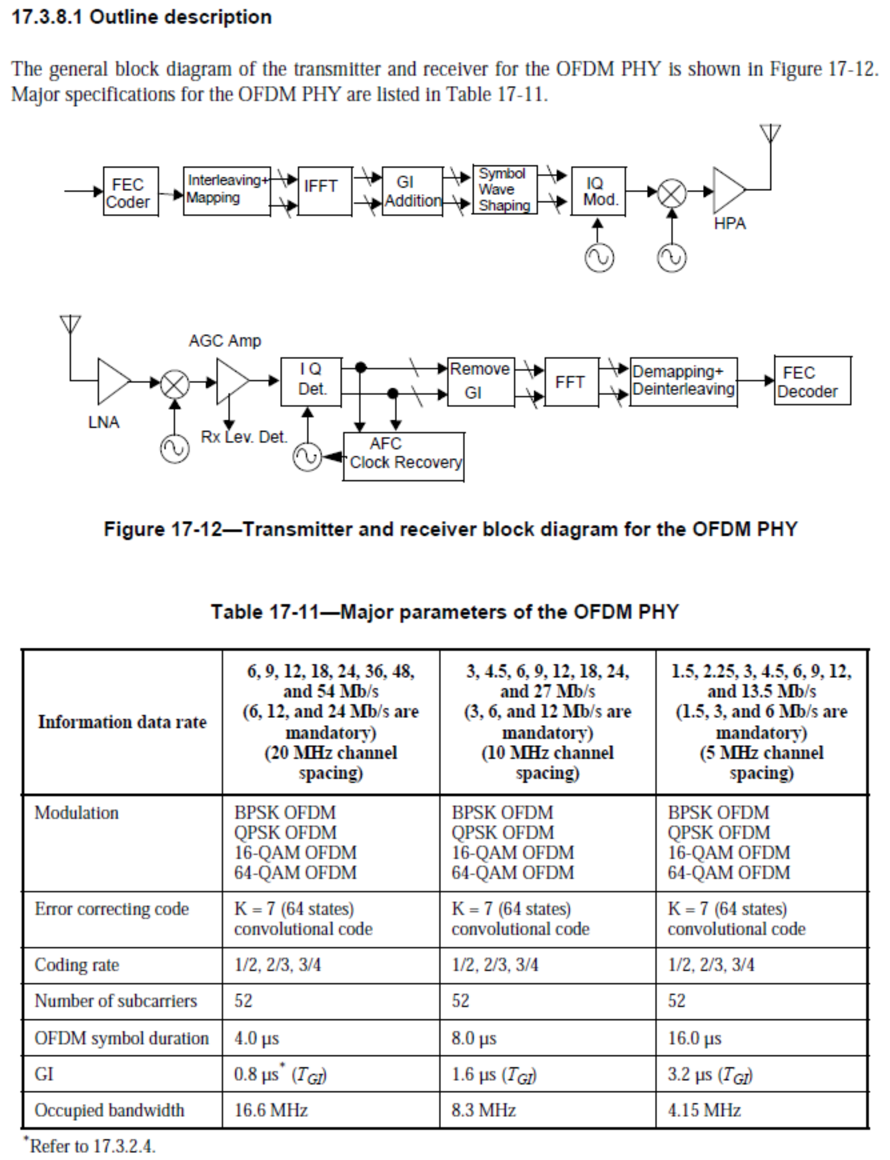
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

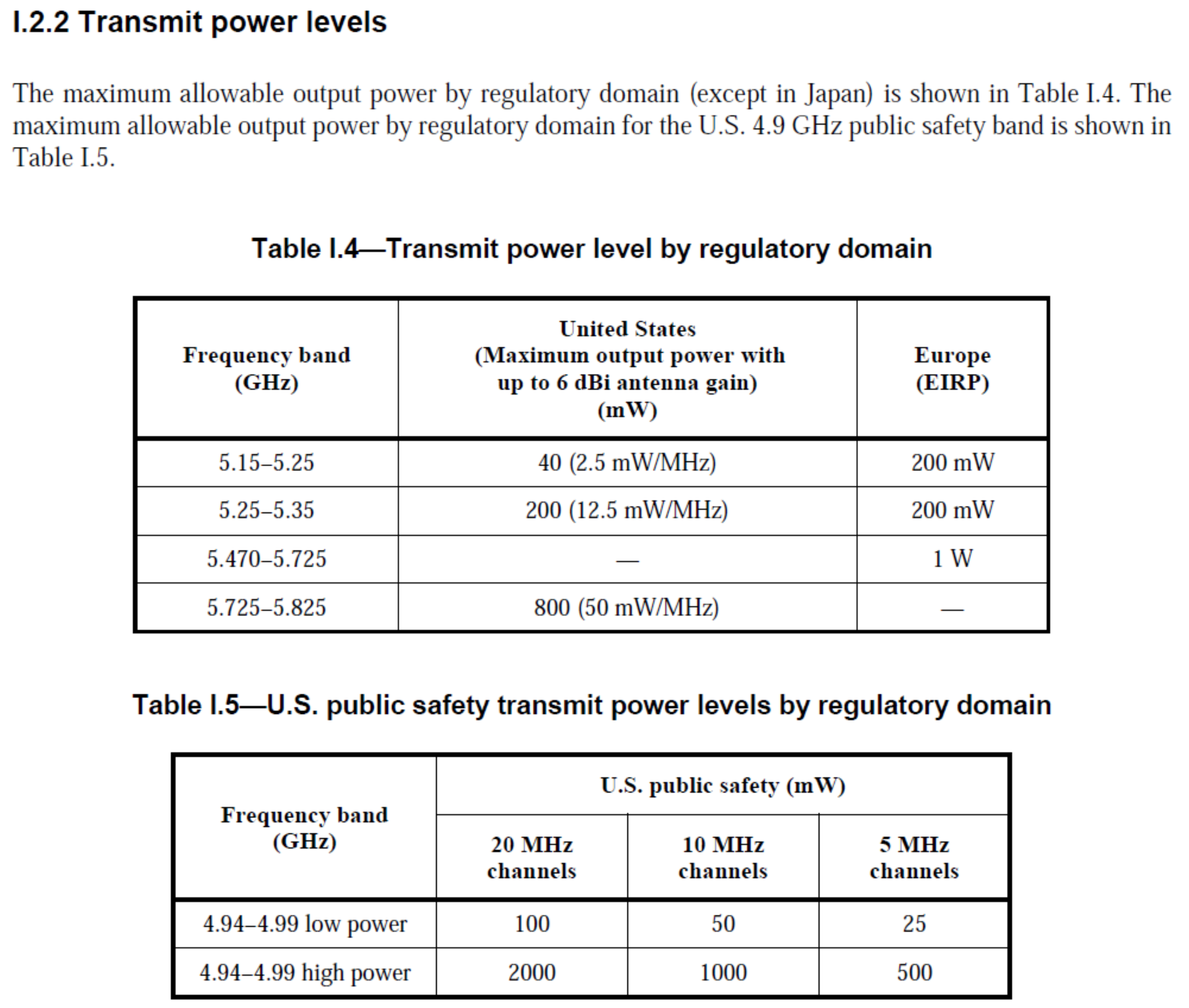
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 See, e.g., 802.11-2007 § I.2.2

I.2.2 Transmit power levels

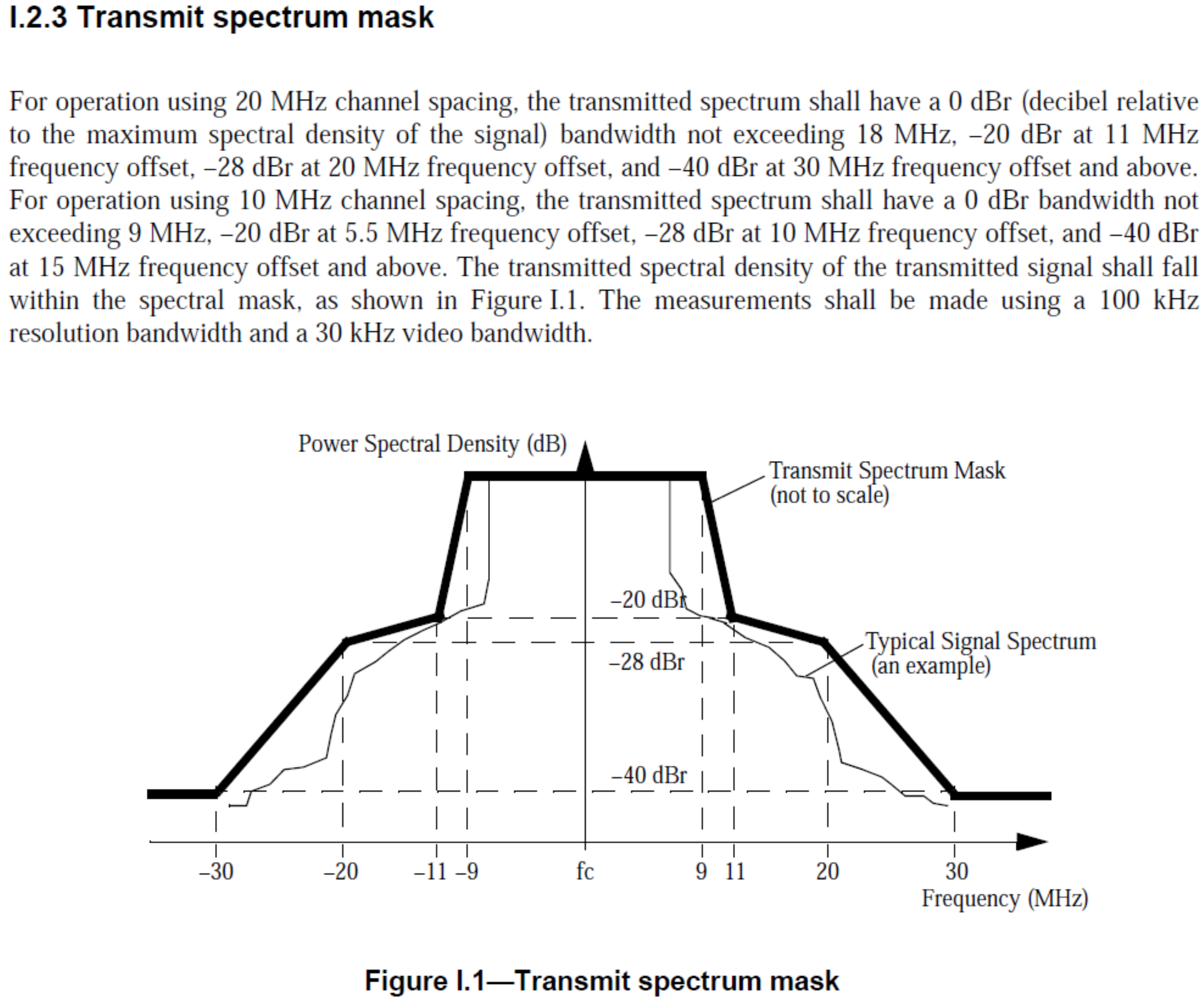
The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

Table I.4—Transmit power level by regulatory domain

Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

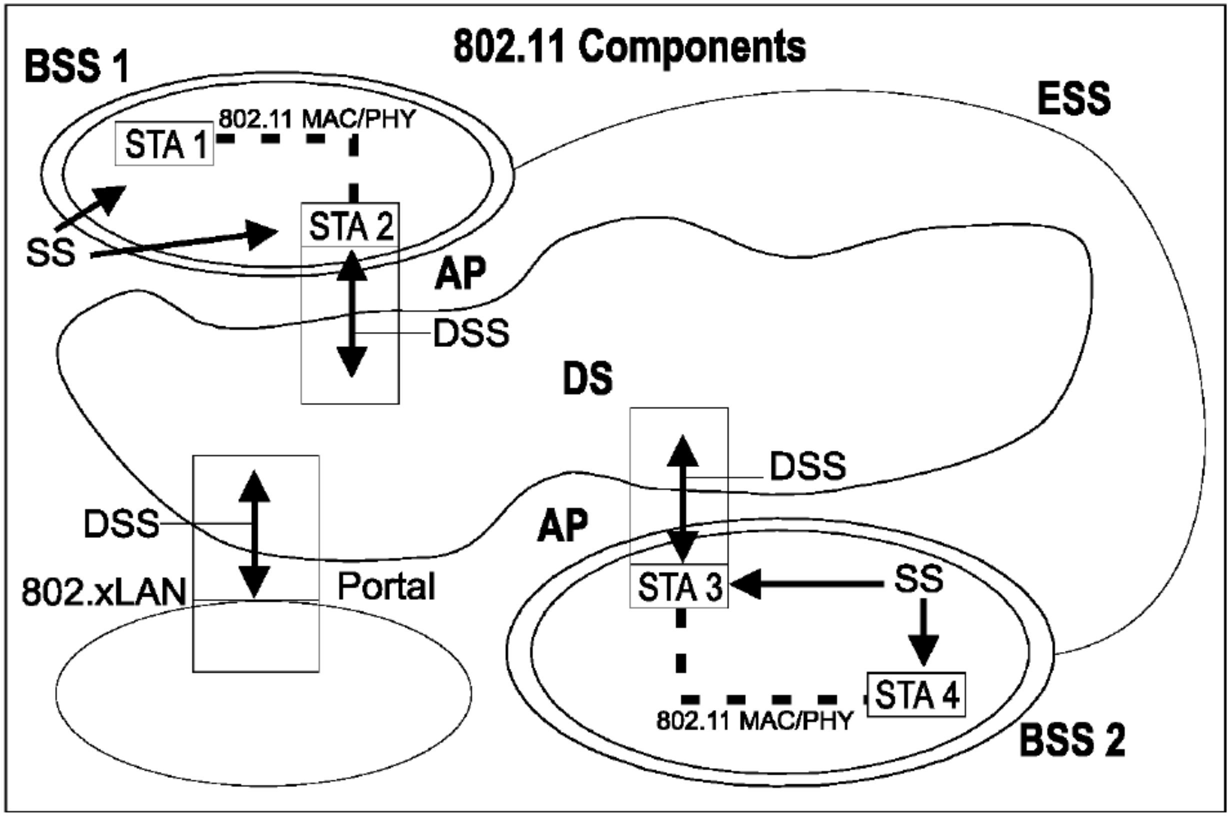
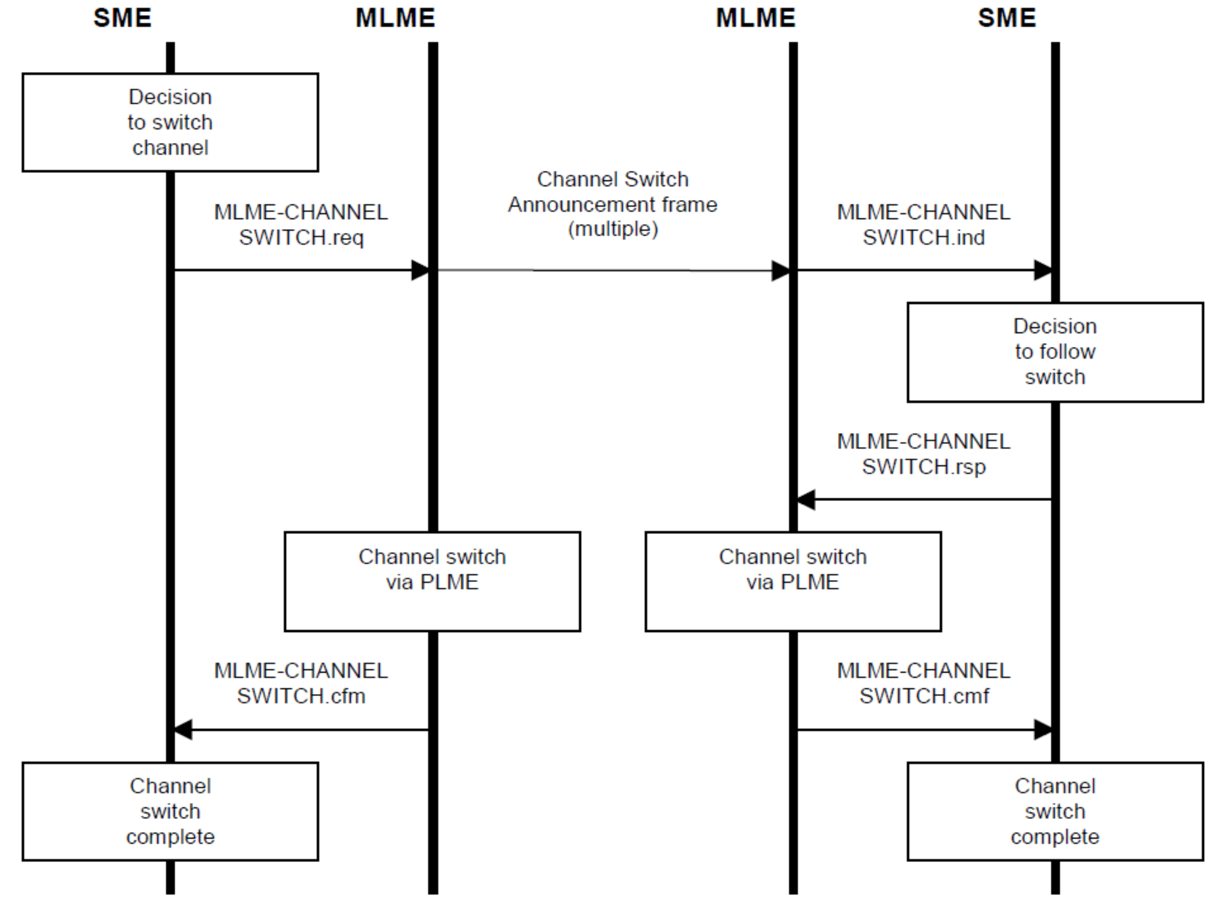
<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

Figure 5-7—Complete IEEE 802.11 architecture

See, e.g., 802.11-2007 Figure 5-7</td></tr>
</table>

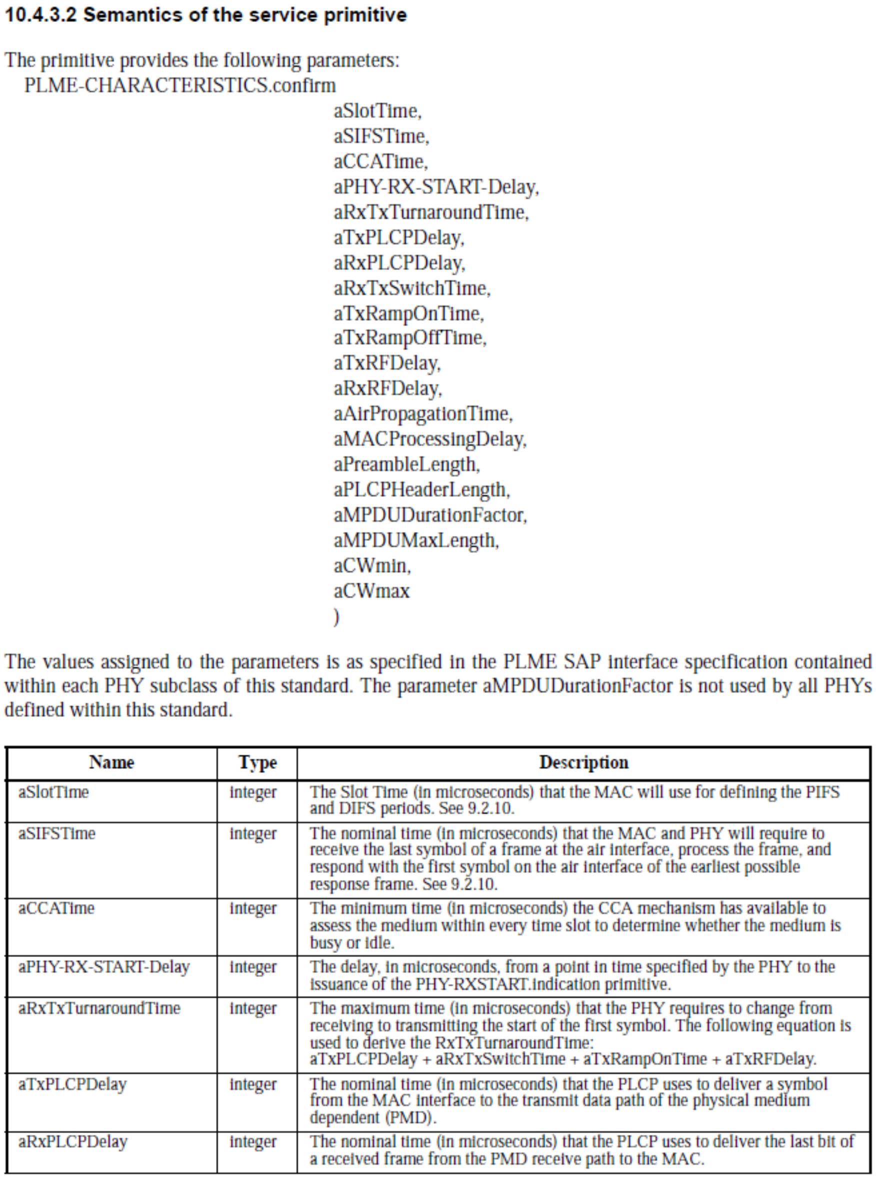
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.10] transmitting the amplified combined up-converted signal on a first antenna,	802.11-2007 discloses “transmitting the amplified combined up-converted signal on a first antenna.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



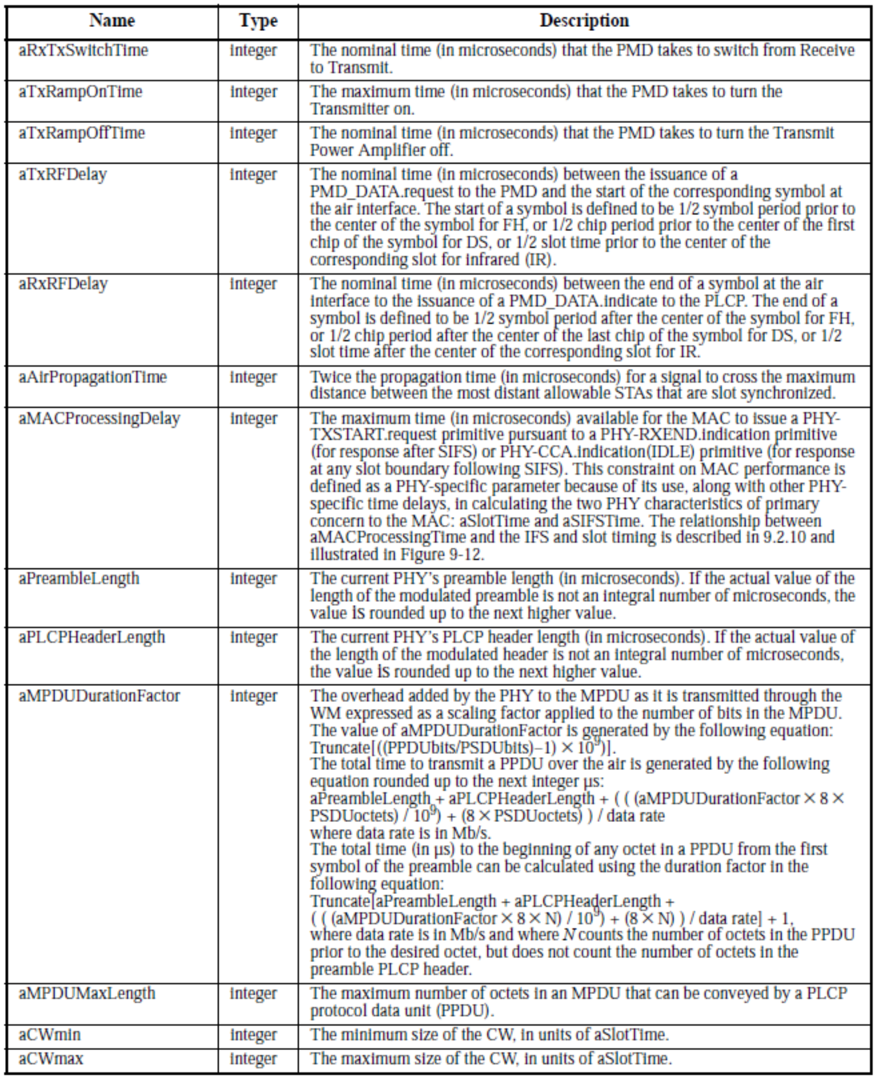
10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

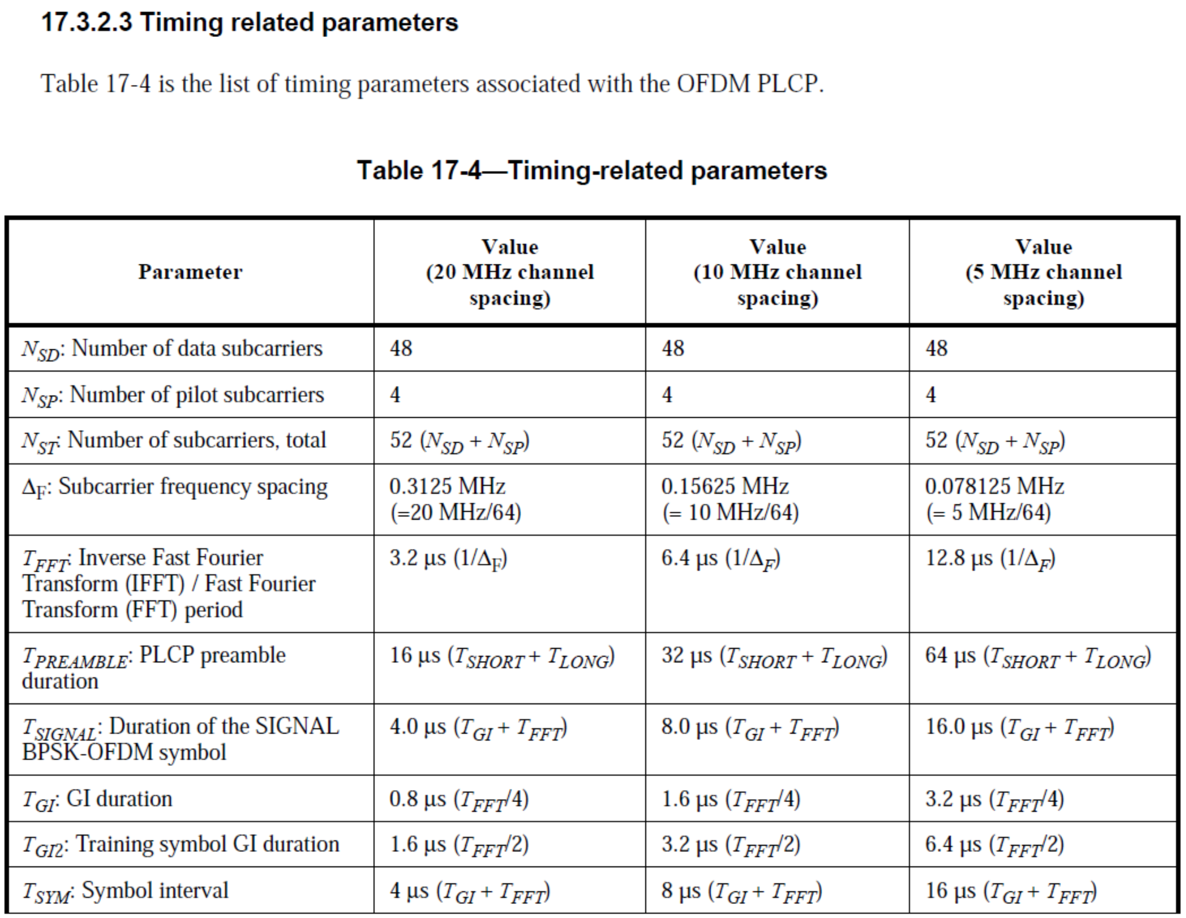
Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz
(=20 MHz/64)</td><td>0.15625 MHz
(= 10 MHz/64)</td><td>0.078125 MHz
(= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 µs ($1/\Delta_F$)</td><td>6.4 µs ($1/\Delta_F$)</td><td>12.8 µs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 µs ($T_{SHORT} + T_{LONG}$)</td><td>32 µs ($T_{SHORT} + T_{LONG}$)</td><td>64 µs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 µs ($T_{GI} + T_{FFT}$)</td><td>8.0 µs ($T_{GI} + T_{FFT}$)</td><td>16.0 µs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 µs ($T_{FFT}/4$)</td><td>1.6 µs ($T_{FFT}/4$)</td><td>3.2 µs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 µs ($T_{FFT}/2$)</td><td>3.2 µs ($T_{FFT}/2$)</td><td>6.4 µs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 µs ($T_{GI} + T_{FFT}$)</td><td>8 µs ($T_{GI} + T_{FFT}$)</td><td>16 µs ($T_{GI} + T_{FFT}$)</td></tr>
</table>
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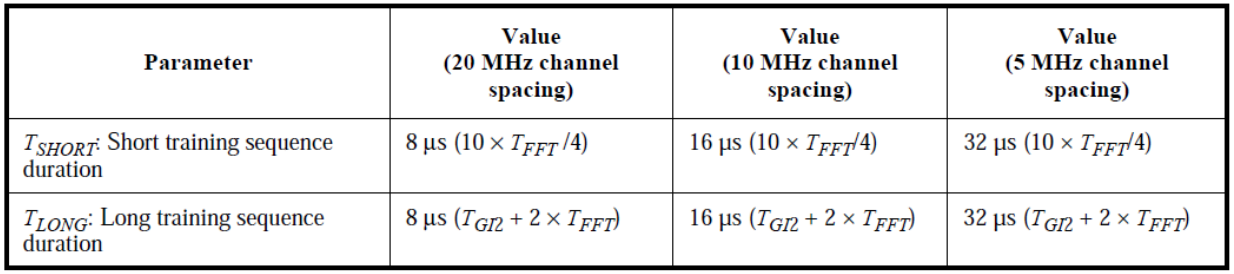
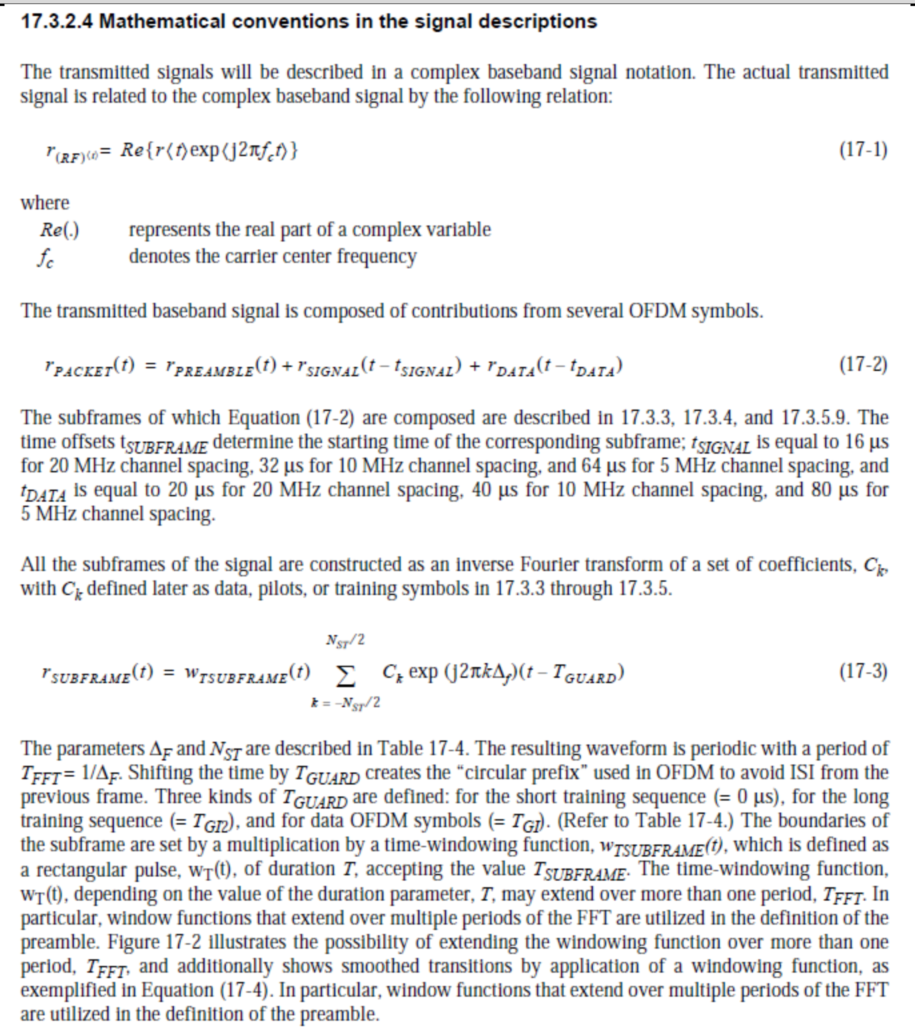
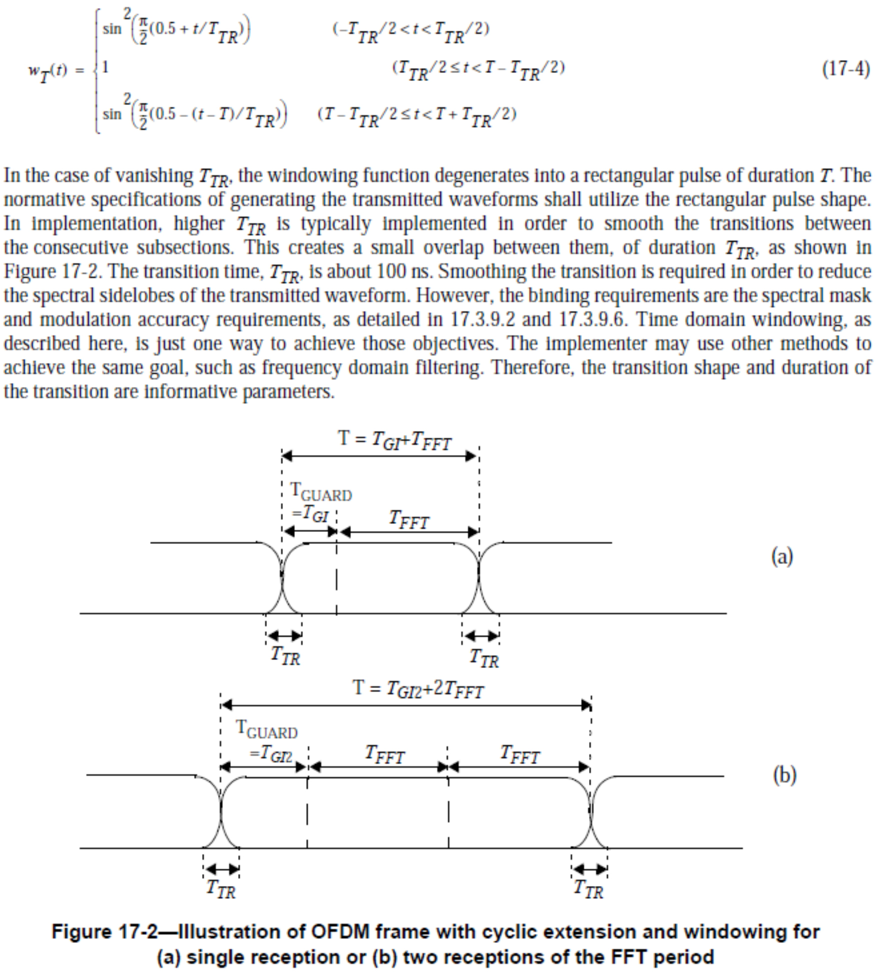
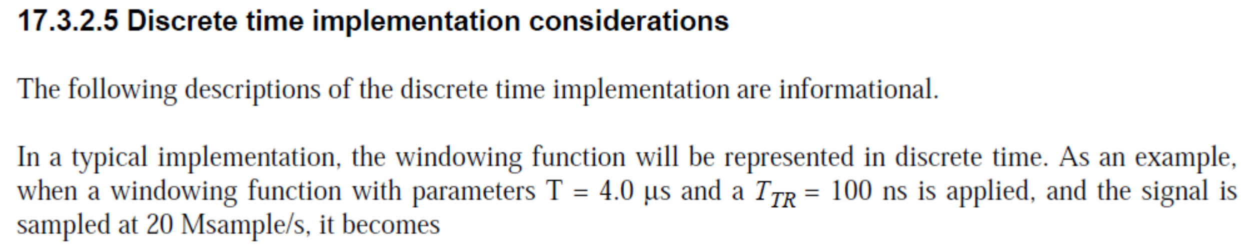
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


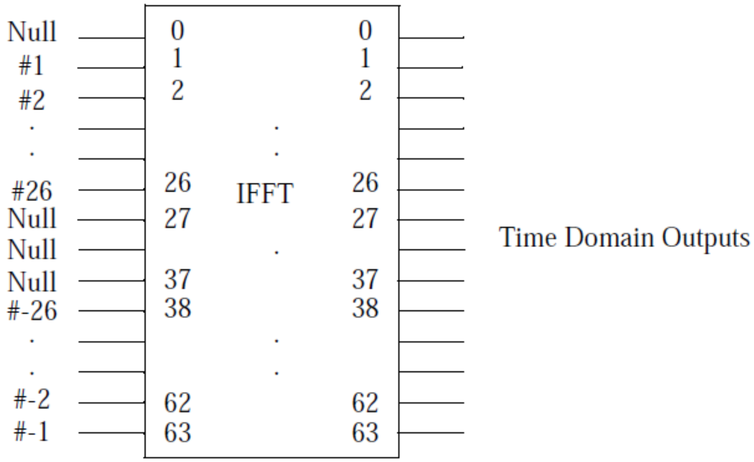
<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 μs (10 × T_{FFT} /4)</td><td>16 μs (10 × T_{FFT}/4)</td><td>32 μs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 μs (T_{GI2} + 2 × T_{FFT})</td><td>16 μs (T_{GI2} + 2 × T_{FFT})</td><td>32 μs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>

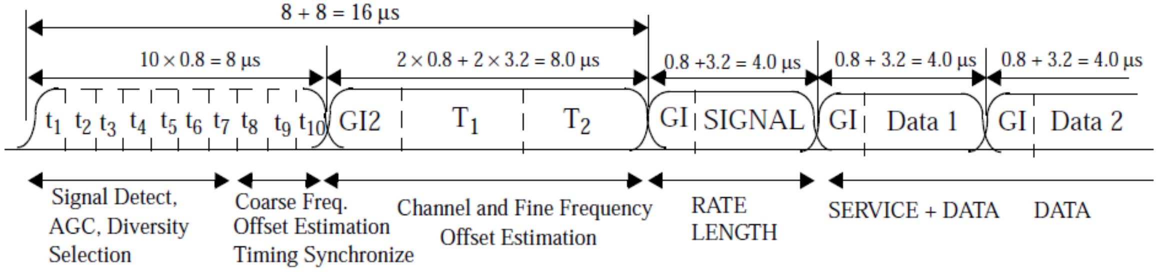
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

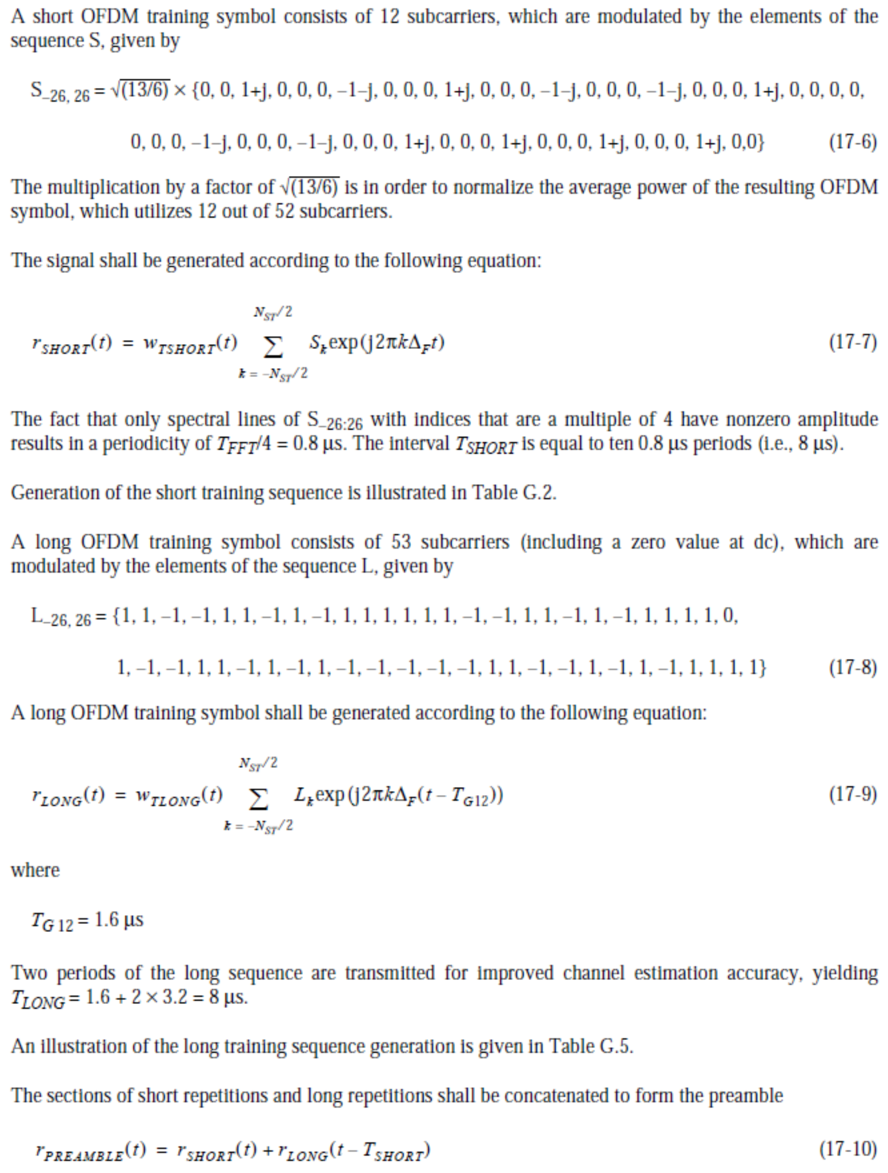
Claim 10 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)(t)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ (17-4) In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 10 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

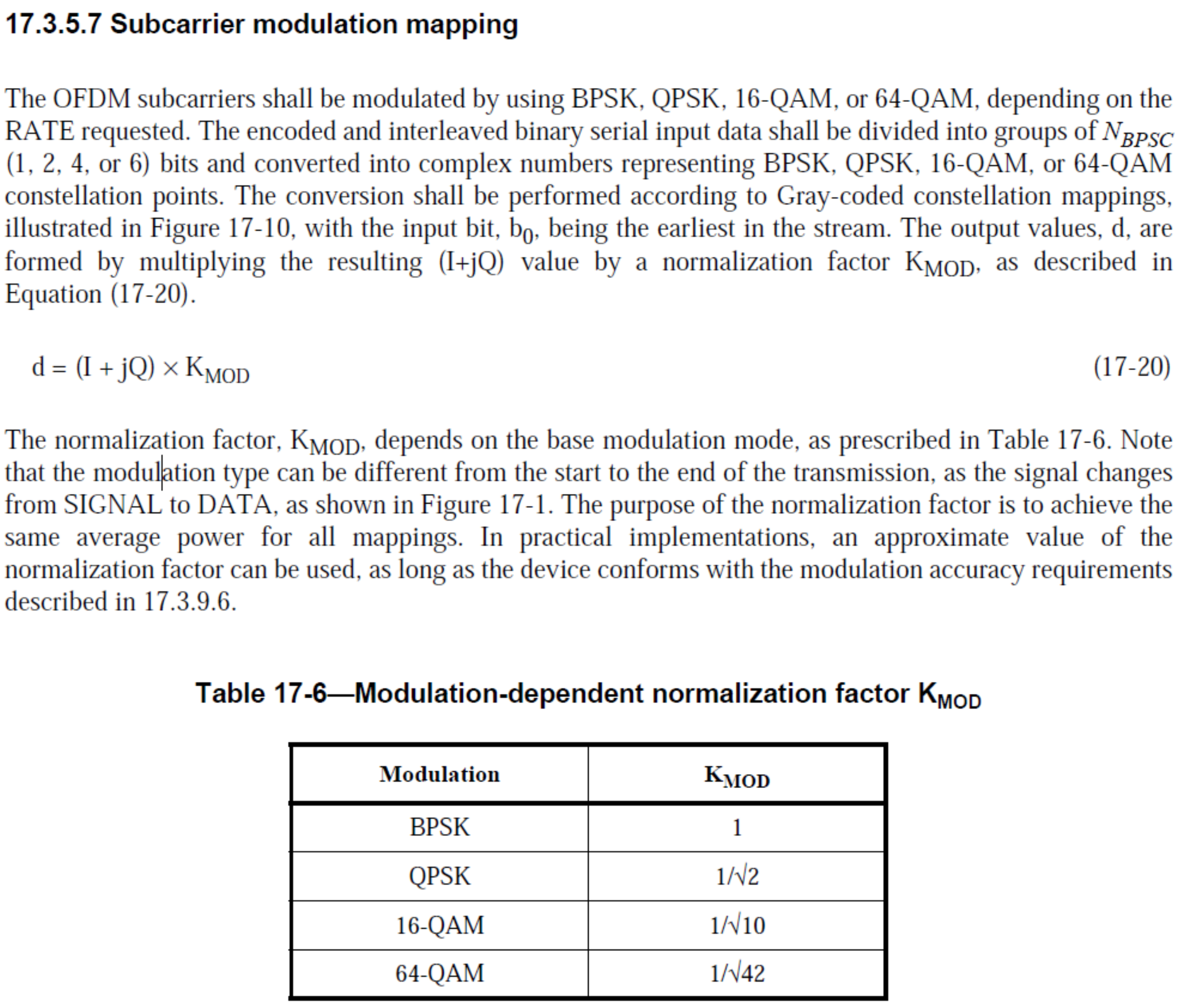
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 10 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


<h3>17.3.5.7 Subcarrier modulation mapping</h3>

<p>The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).</p>

<p>$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$</p>

<p>The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.</p>

<p>Table 17-6—Modulation-dependent normalization factor K_{MOD}</p>

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

<p>See, e.g., 802.11-2007 § 17.3.5.7</p>
</td></tr>
</table>

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	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,\,n} \equiv d_{k\,+\,N_{SD}\,\times\,n}\,, \qquad k = 0,\,\ldots\, N_{SD} - 1,\ n = 0,\,\ldots\, N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,\,n}(t) \;=\; w_{TSYM}(t)\left(\sum_{k\,=\,0}^{N_{SD}-1} d_{k,\,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n\,+\,1}\sum_{k\,=\,-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) \;=\; \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,\,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

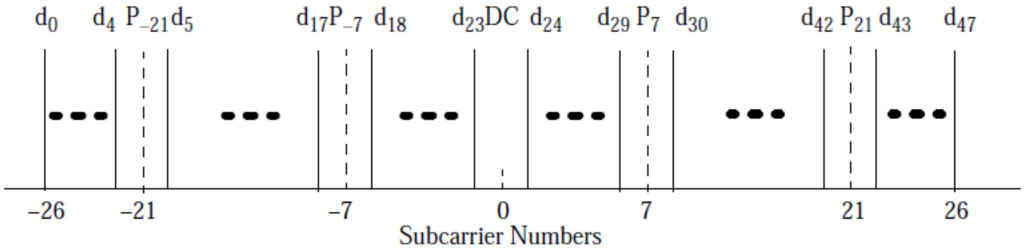


Figure 17-11—Subcarrier frequency allocation

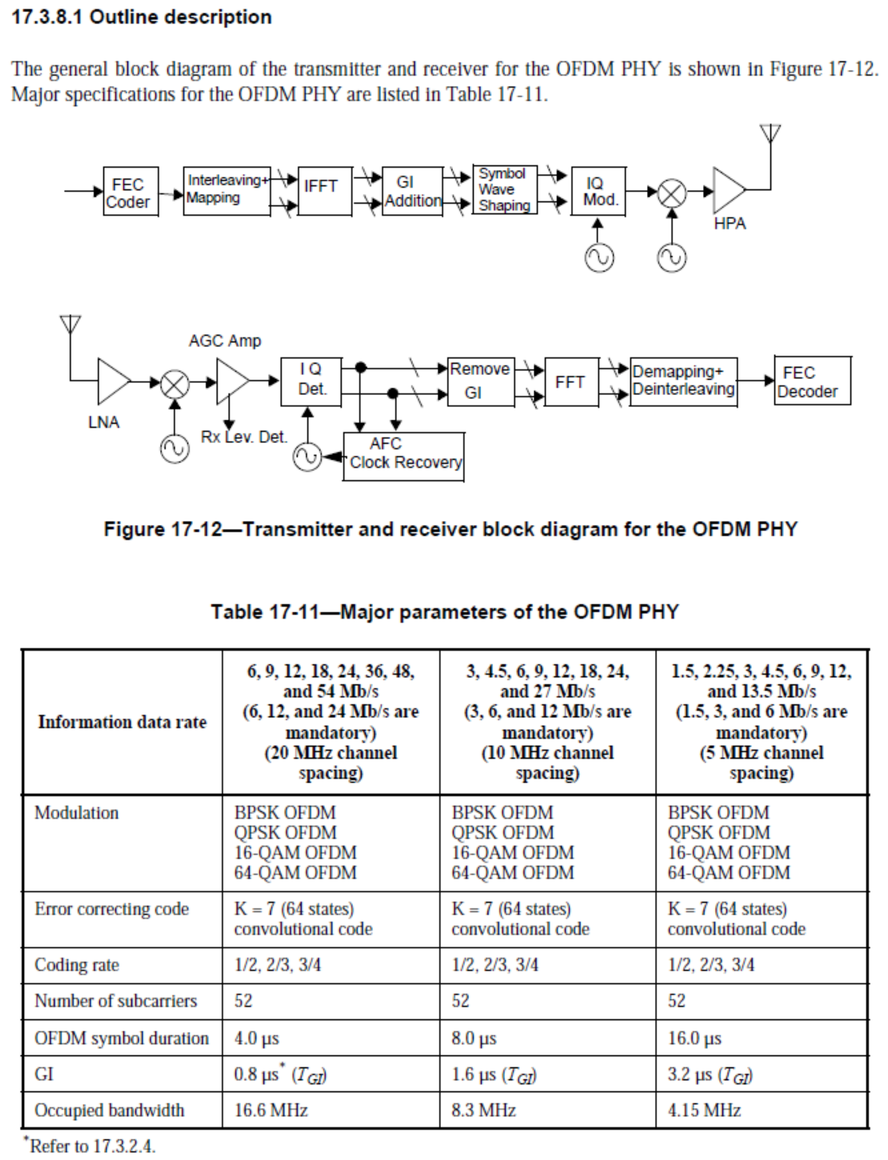
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

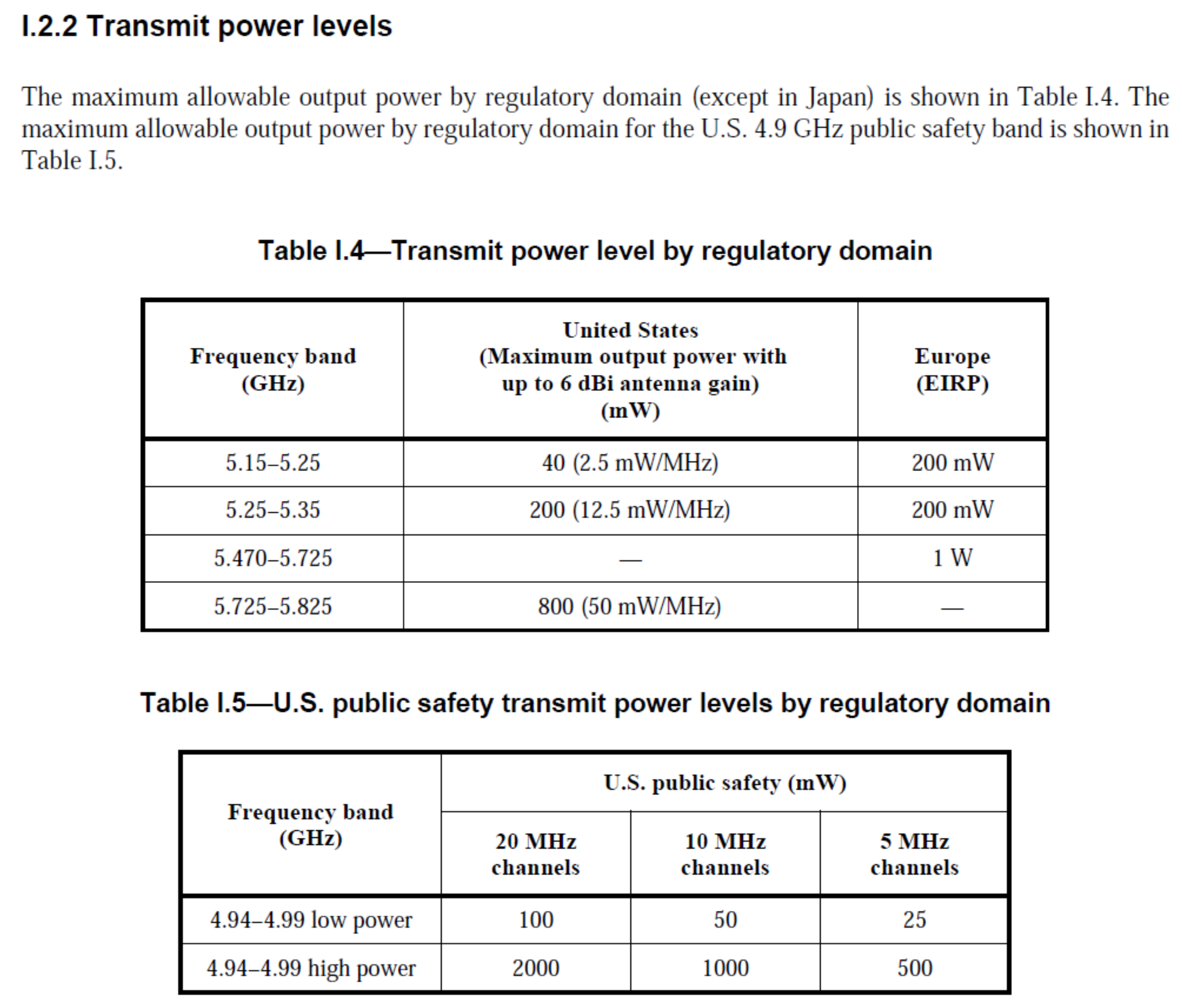
Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

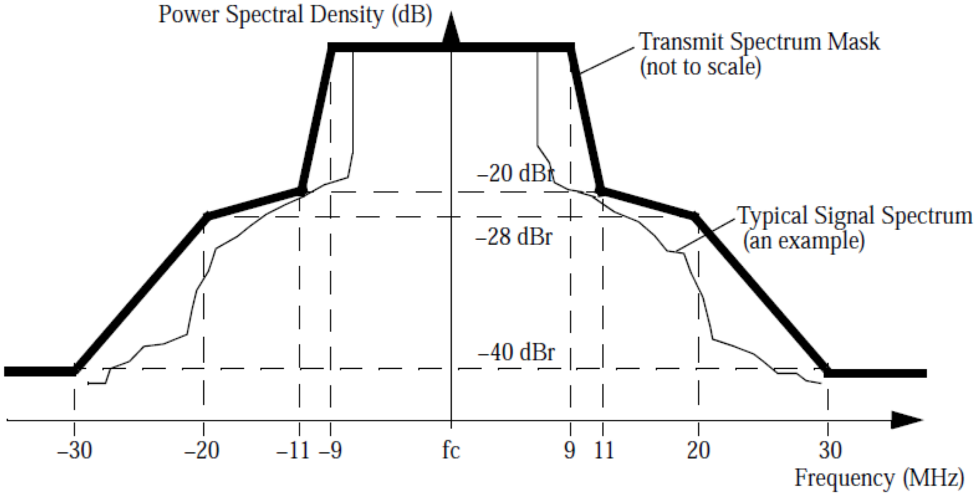
Table I.4—Transmit power level by regulatory domain

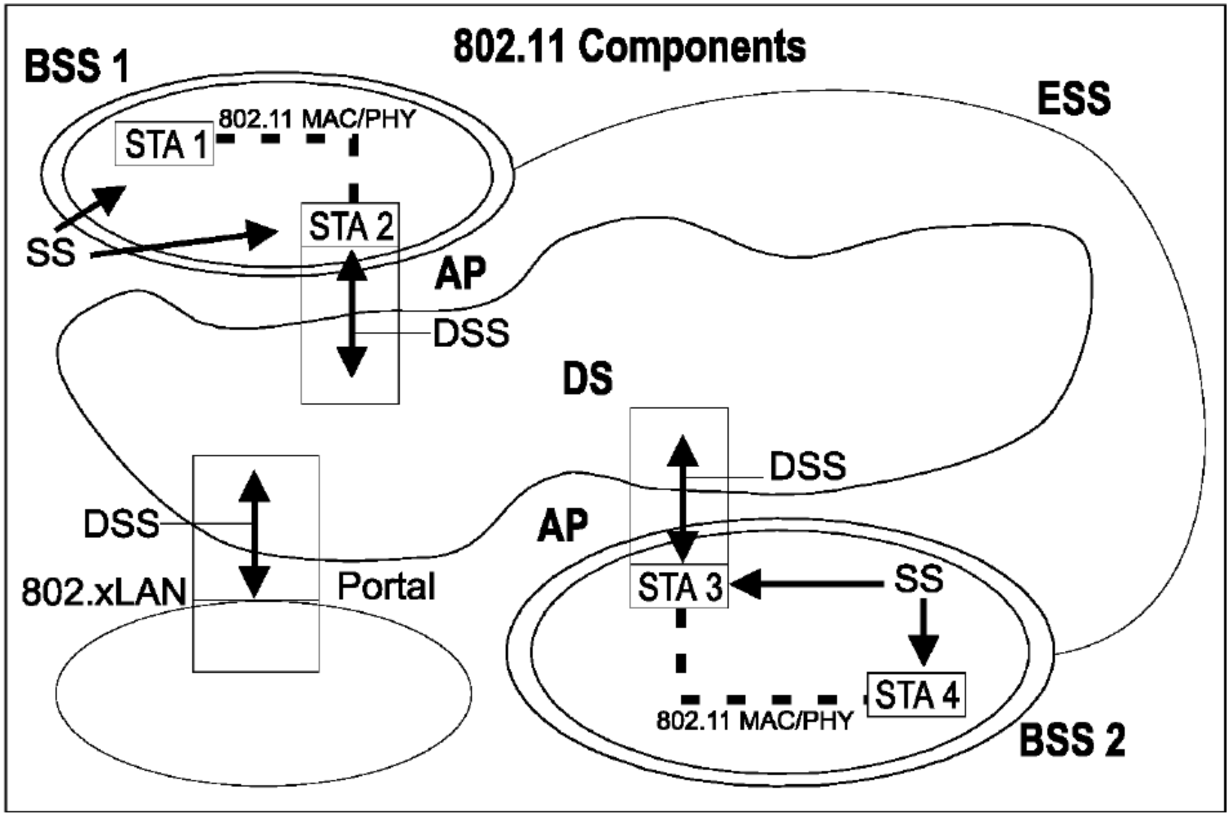
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

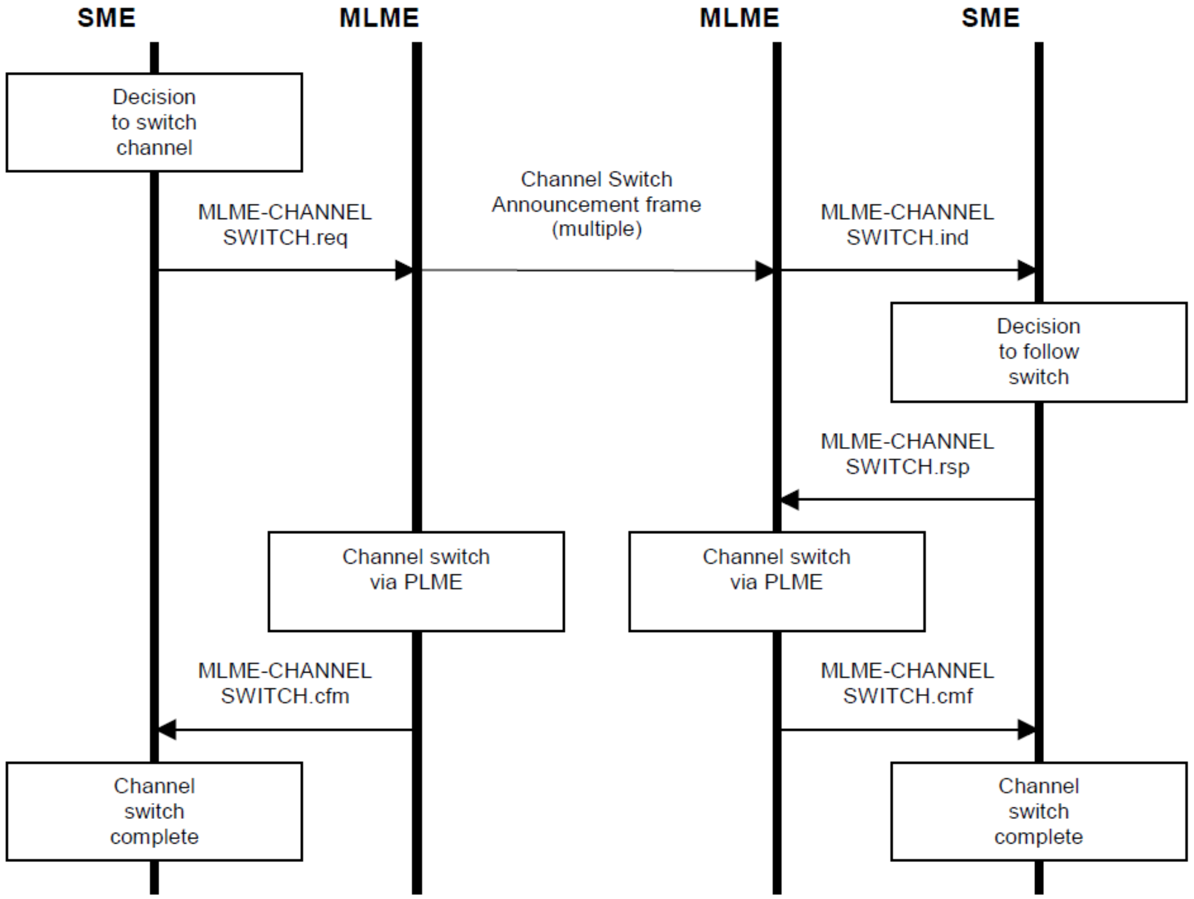
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

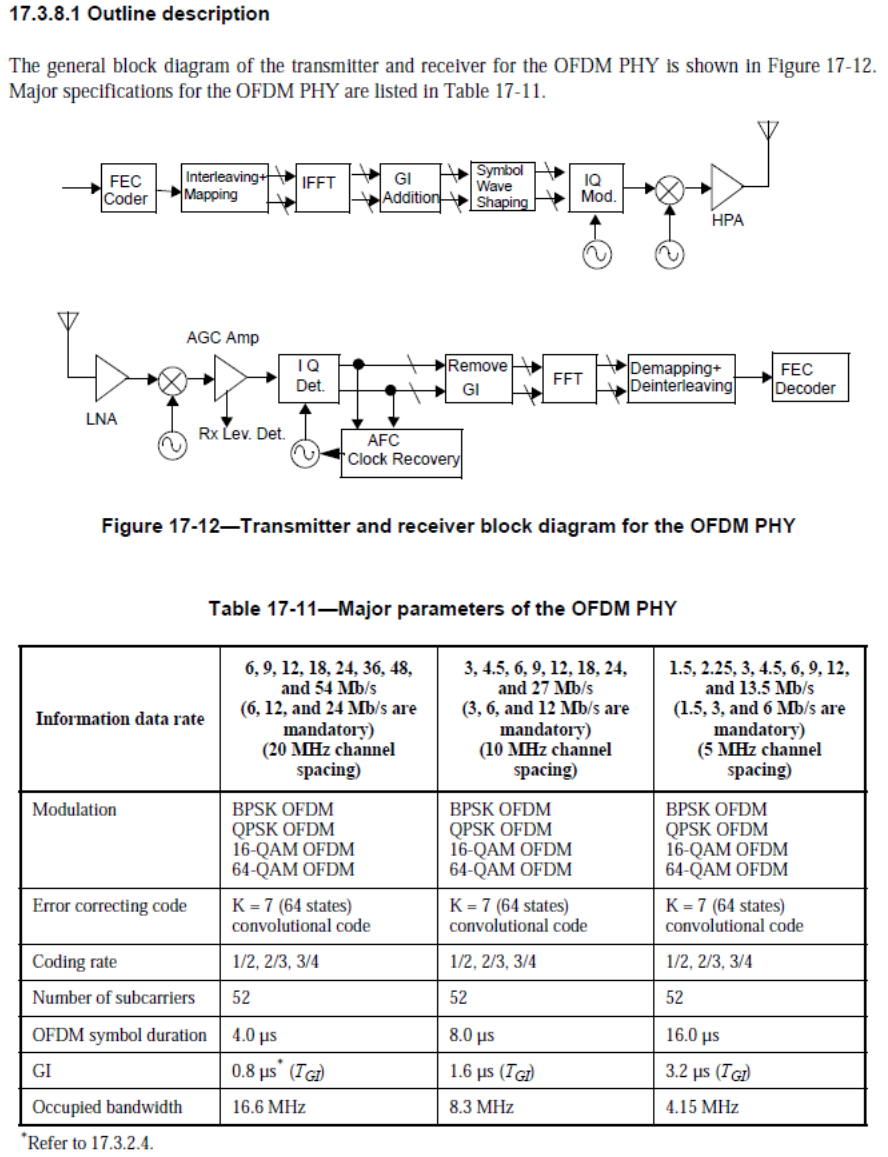
Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 10 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.11] wherein the bandwidth of said power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range.	802.11-2007 discloses “wherein the bandwidth of said power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range.” See, e.g.:

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be

Claim 10 of the ’802 Patent	Prior Art Reference – 802.11-2007
	associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 13 of the '802 Patent	**Prior Art Reference – 802.11-2007**
[13.1] The method of claim 10	802.11-2007 discloses all the elements of claim 10 for all the reasons provided above.
[13.2] wherein the first digital signal is encoded using a first wireless protocol and the second digital signal is encoded using a second wireless protocol.	802.11-2007 discloses "wherein the first digital signal is encoded using a first wireless protocol and the second digital signal is encoded using a second wireless protocol." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

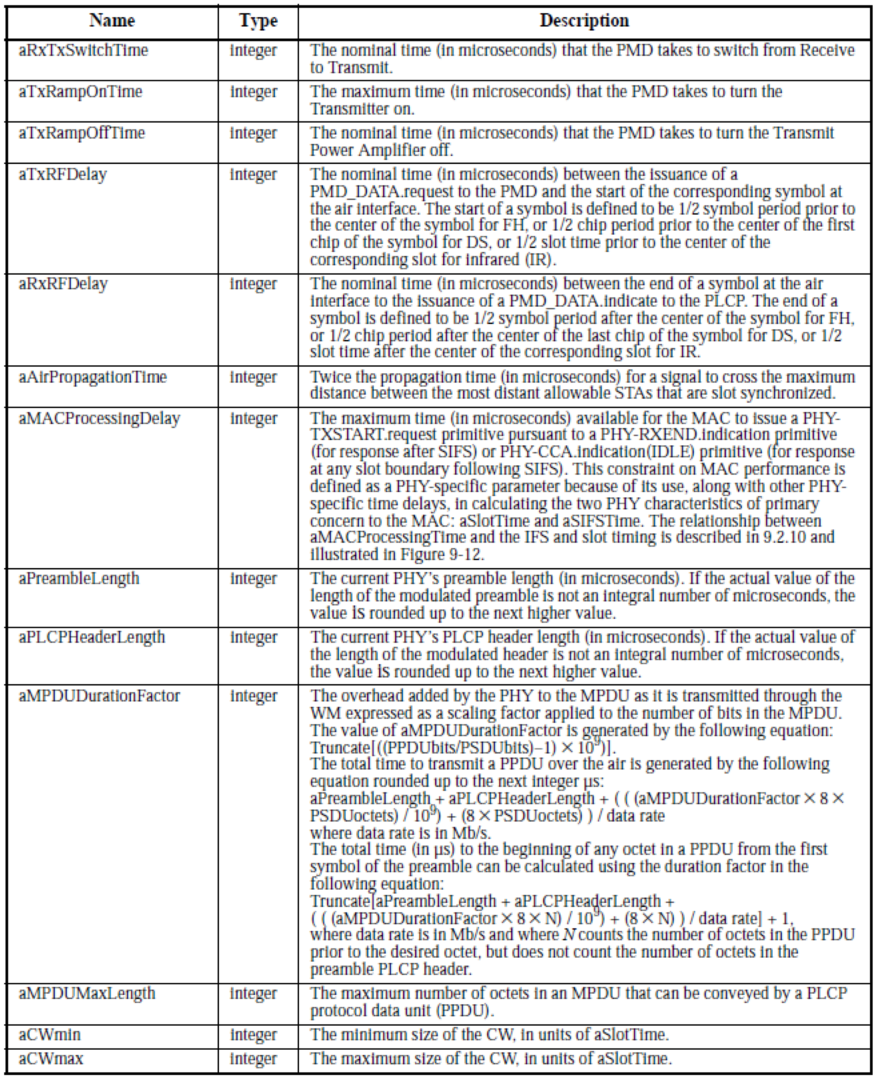
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007

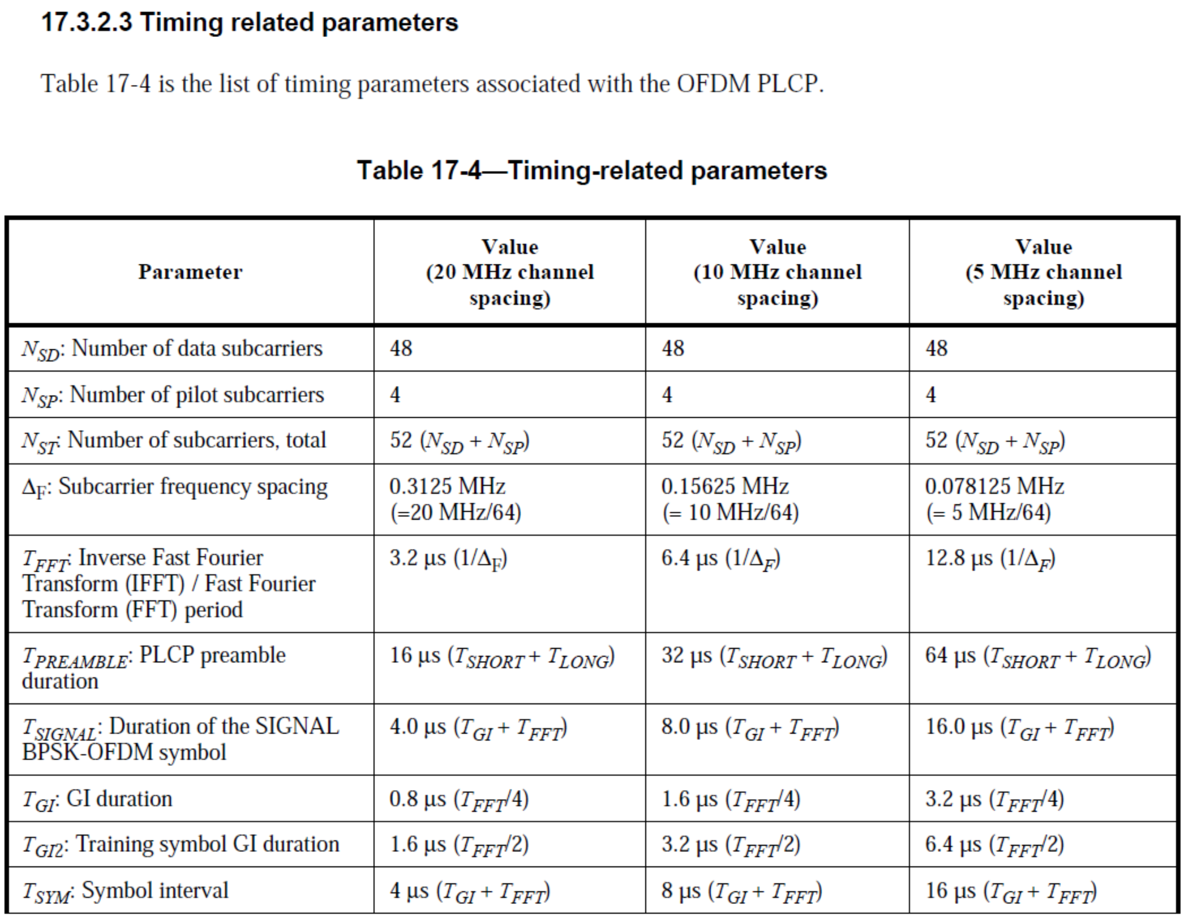


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

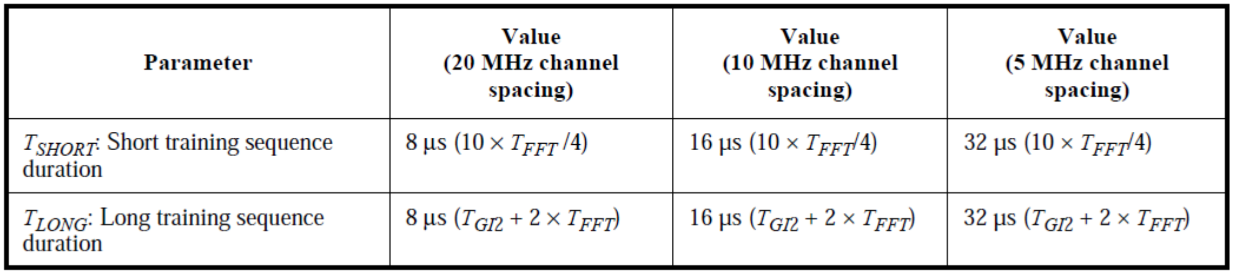
Claim 13 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

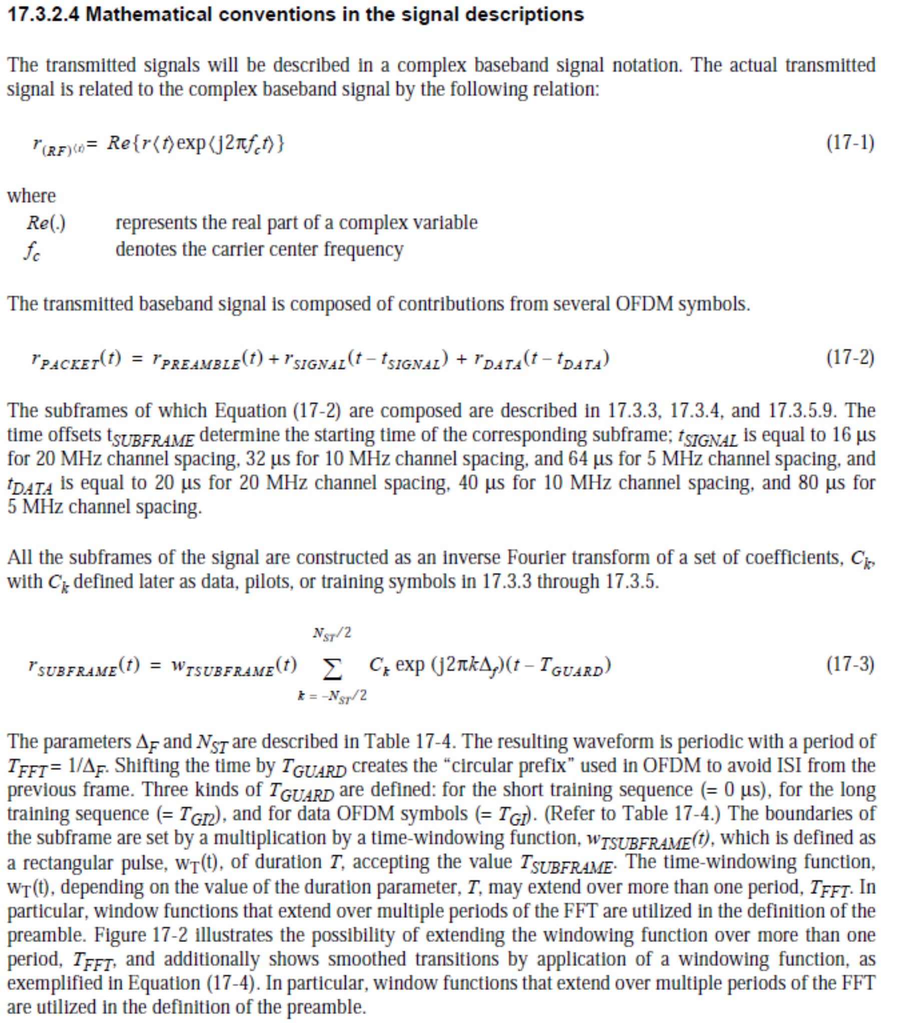
17.3.2.3 Timing related parameters

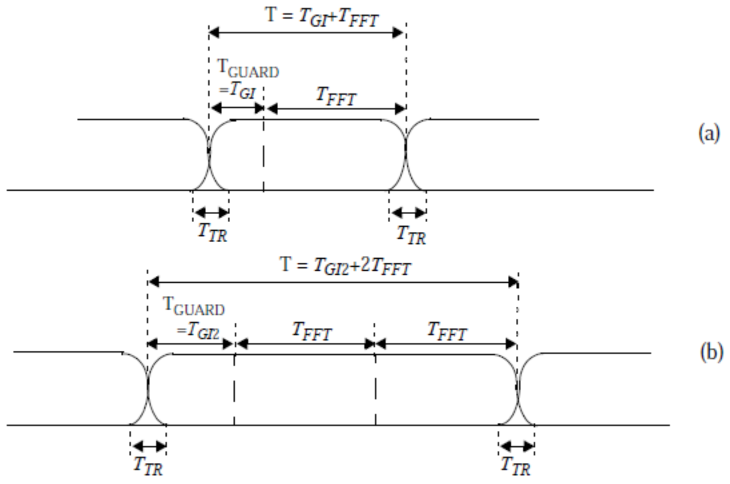
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

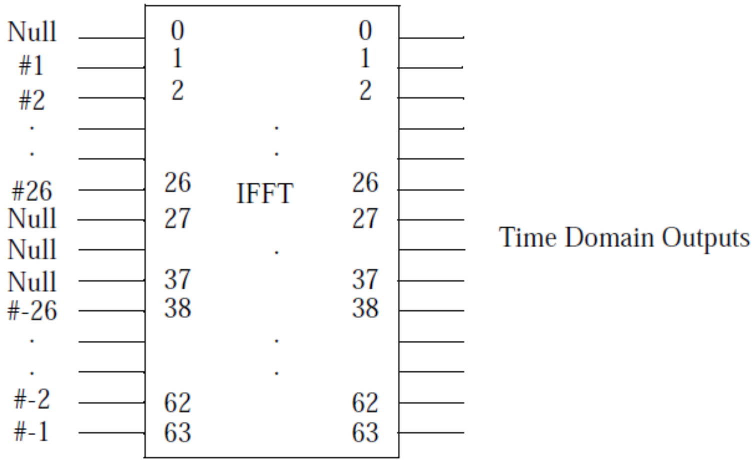
Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

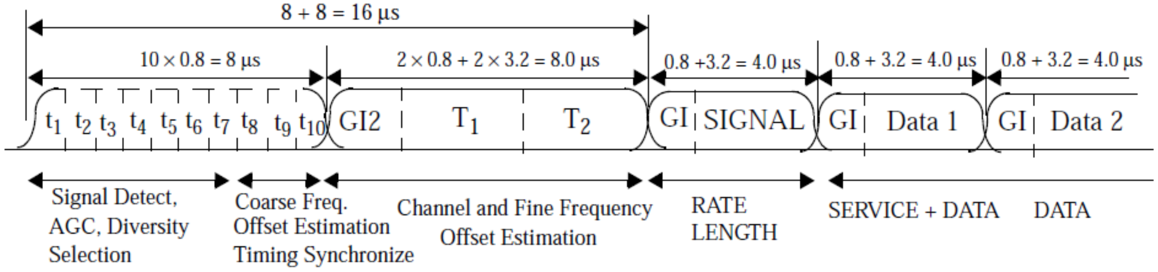
<table>
<tr><th>Claim 13 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

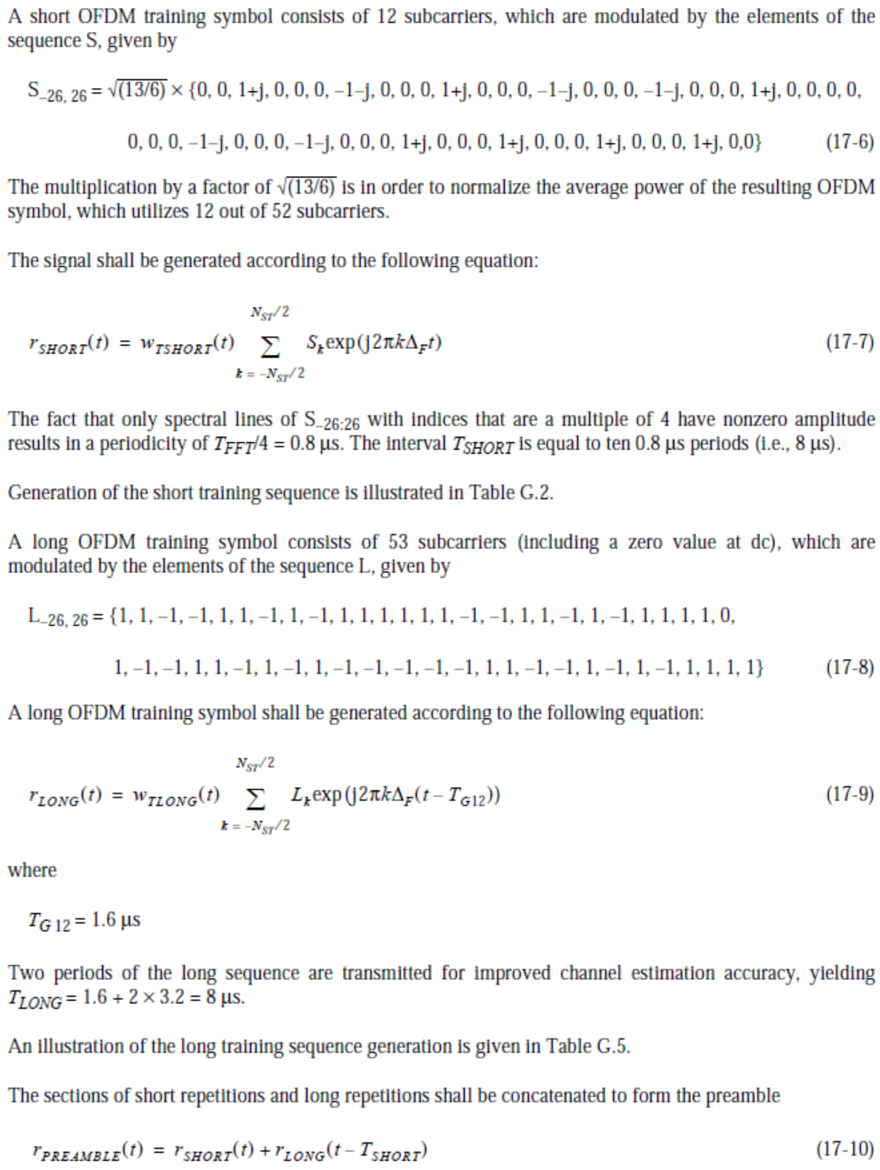
Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 13 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\} \qquad (17\text{-}5)$$ The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of √(13/6) is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F(t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

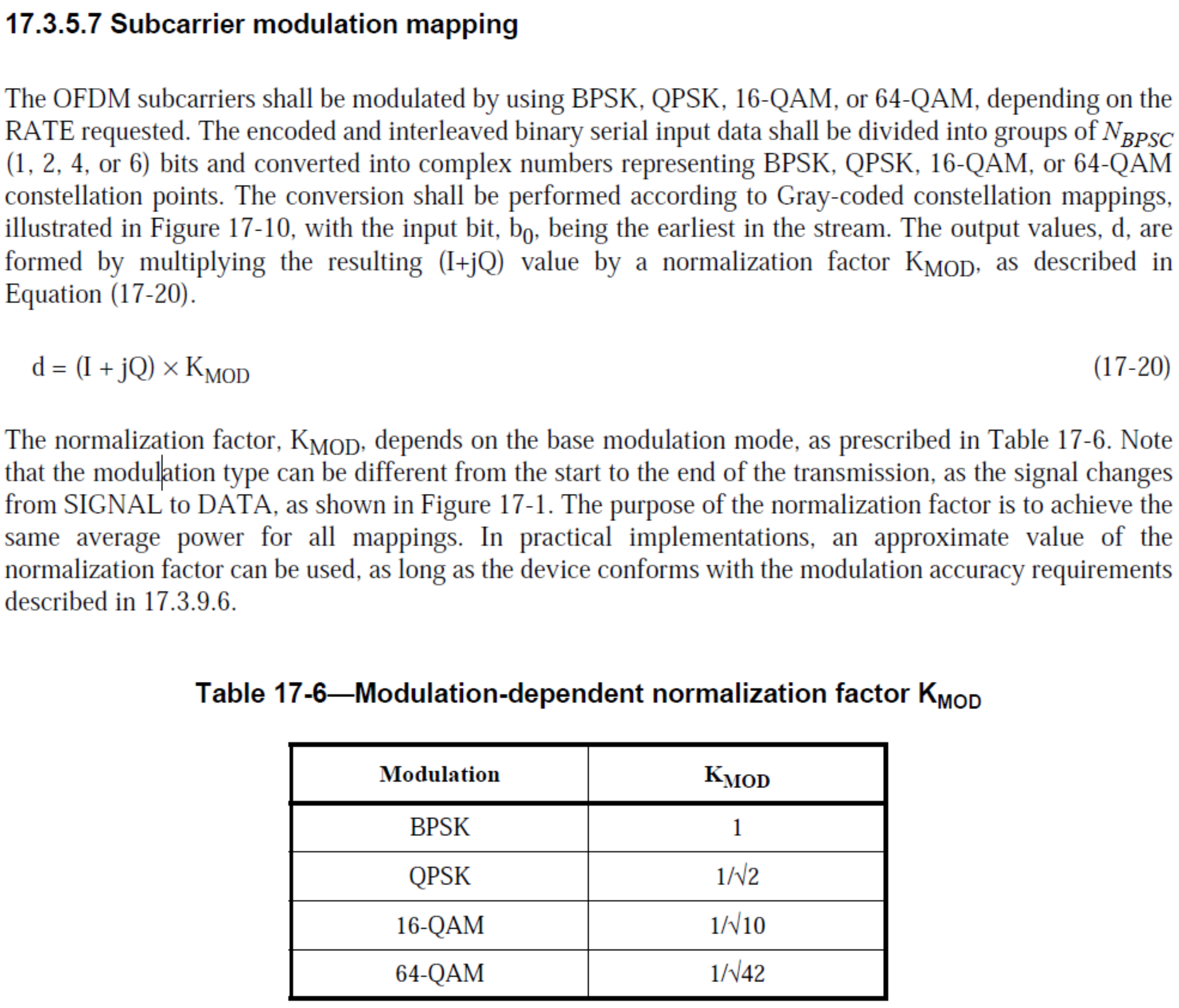
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 13 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$\begin{aligned} r_{DATA,n}(t) = w_{TSYM}(t) \Biggl(& \sum_{k=0}^{N_{SD}-1} d_{k,n} \exp((j2\pi M(k)\Delta_F(t - T_{GI})) \\ & + p_{n+1} \sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t - T_{GI})) \Biggr) \end{aligned} \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \qquad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

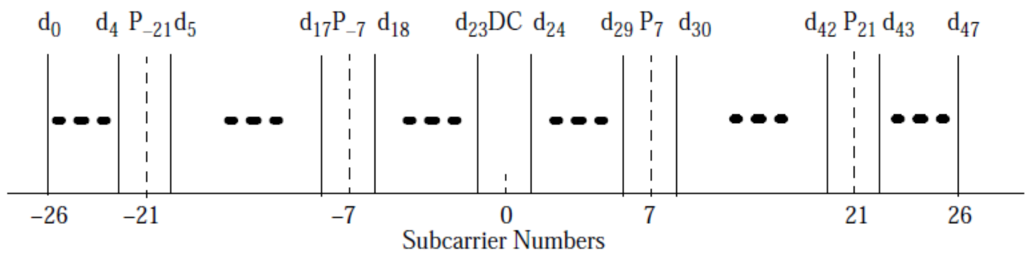


Figure 17-11—Subcarrier frequency allocation

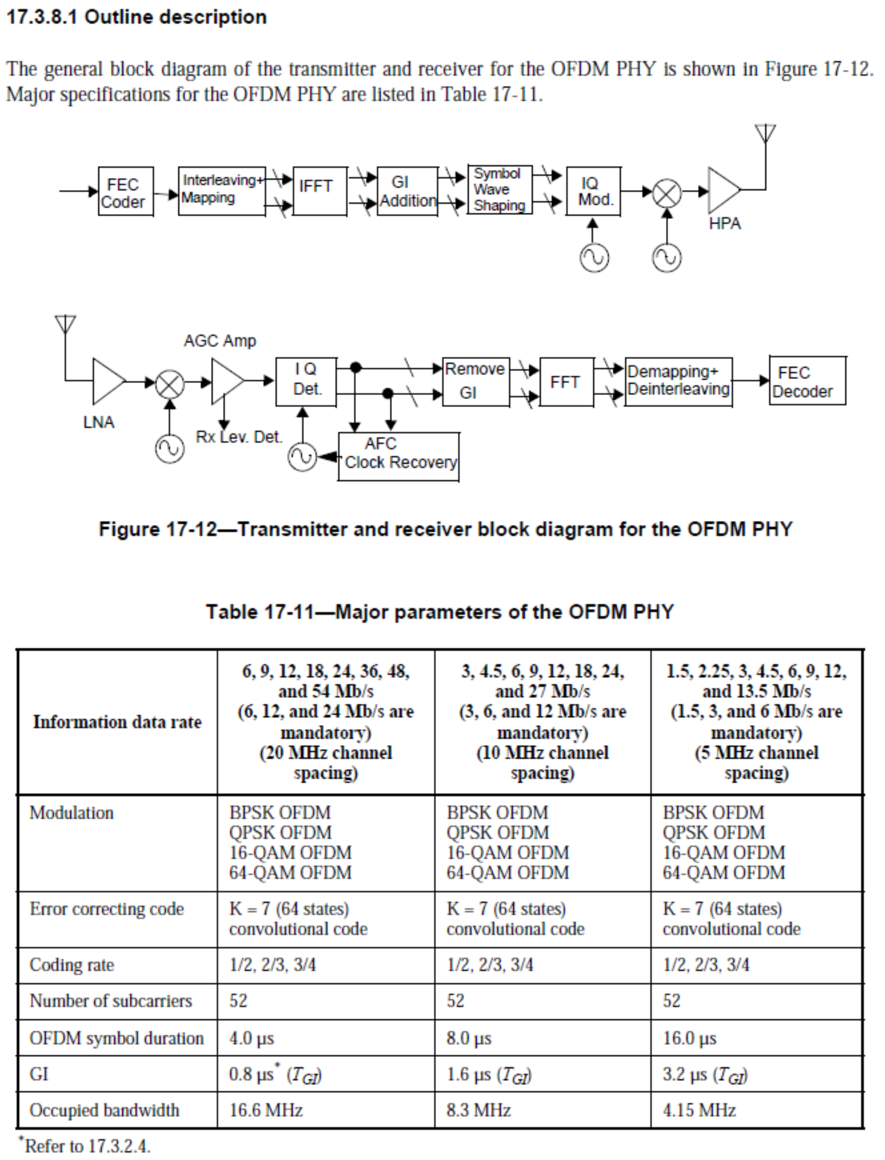
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 13 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

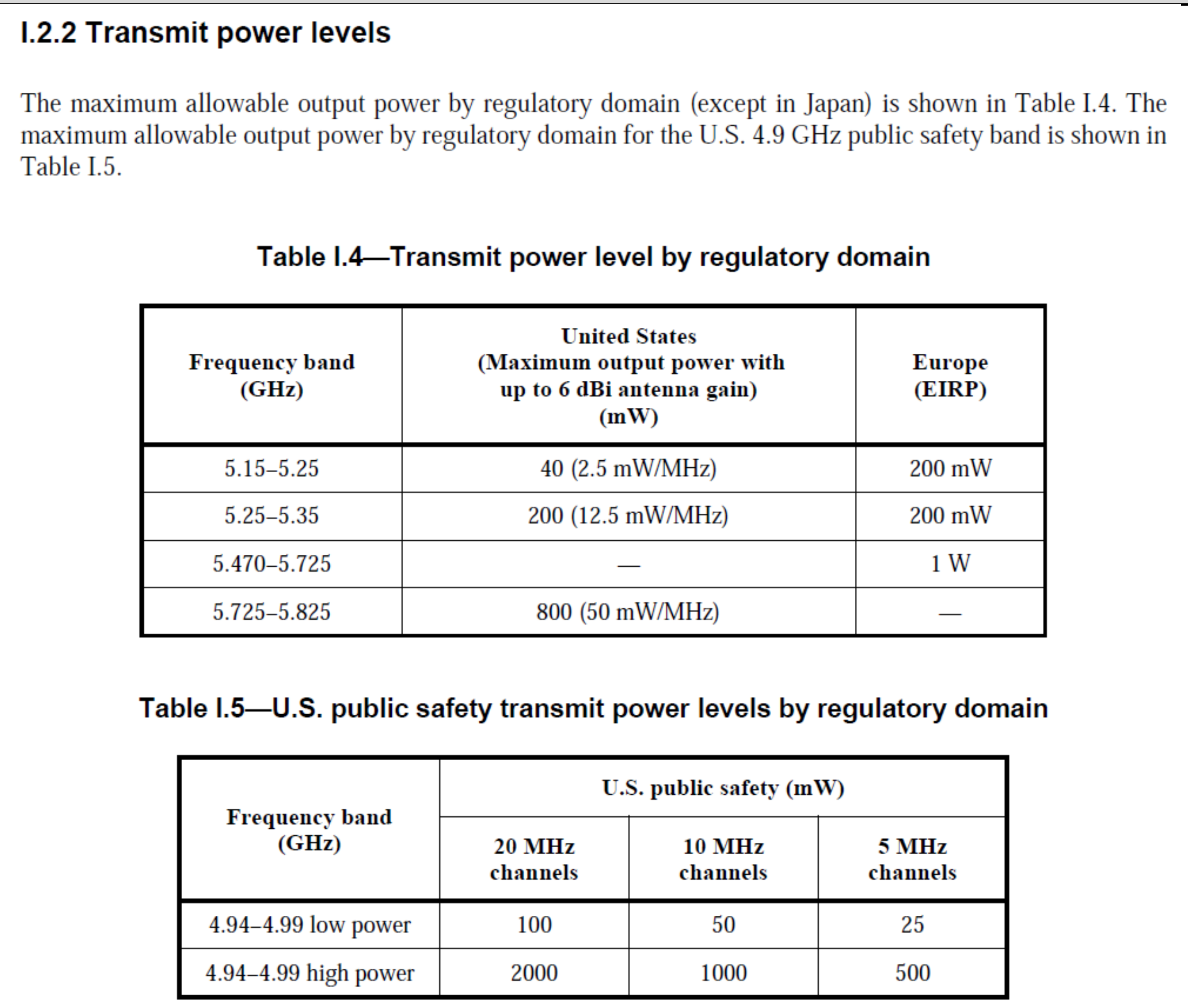
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

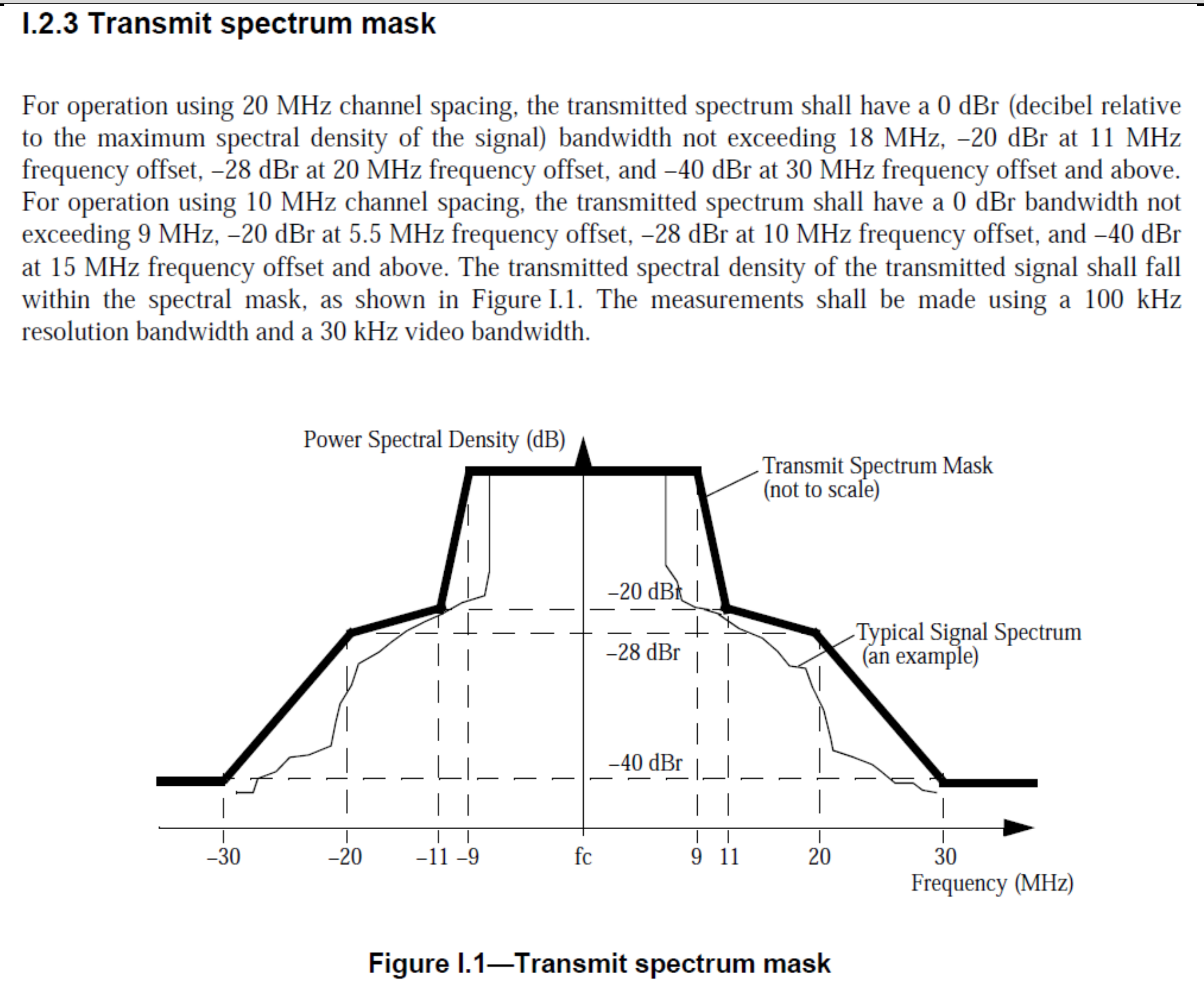
Table I.4—Transmit power level by regulatory domain

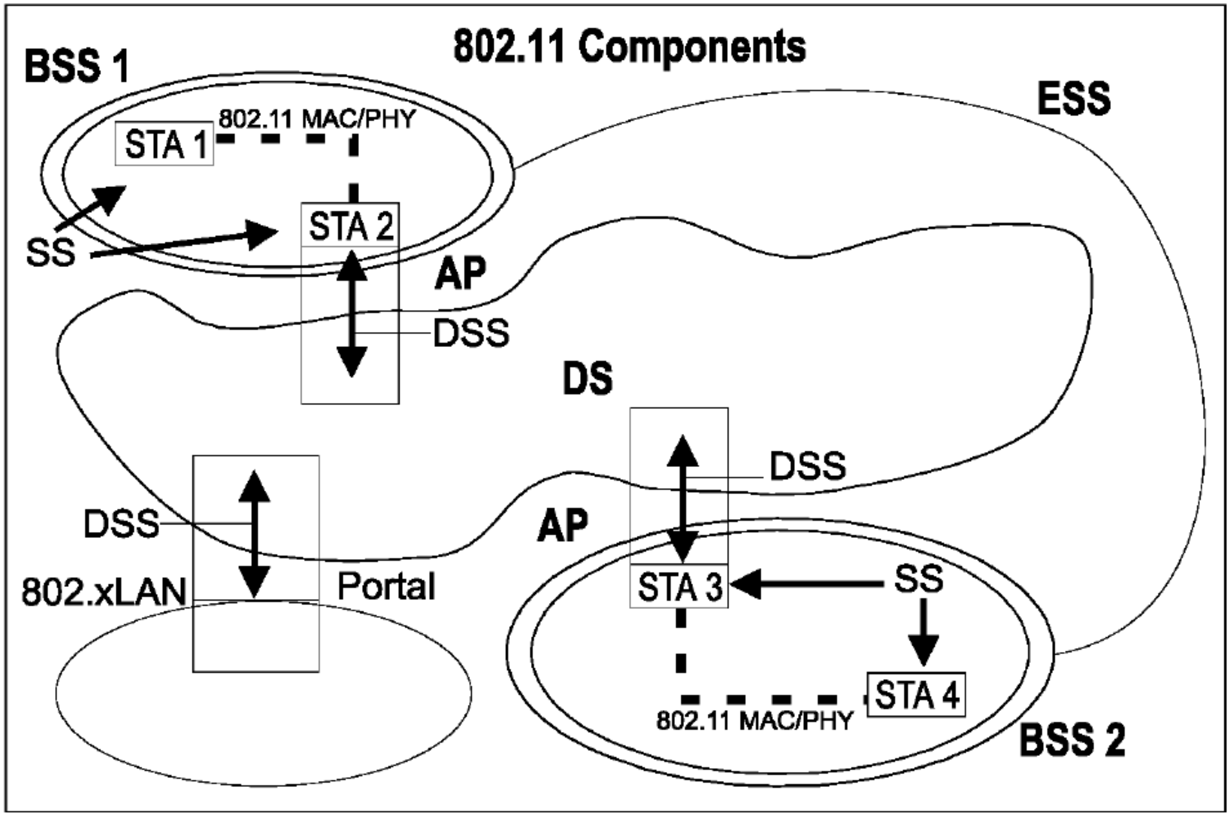
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

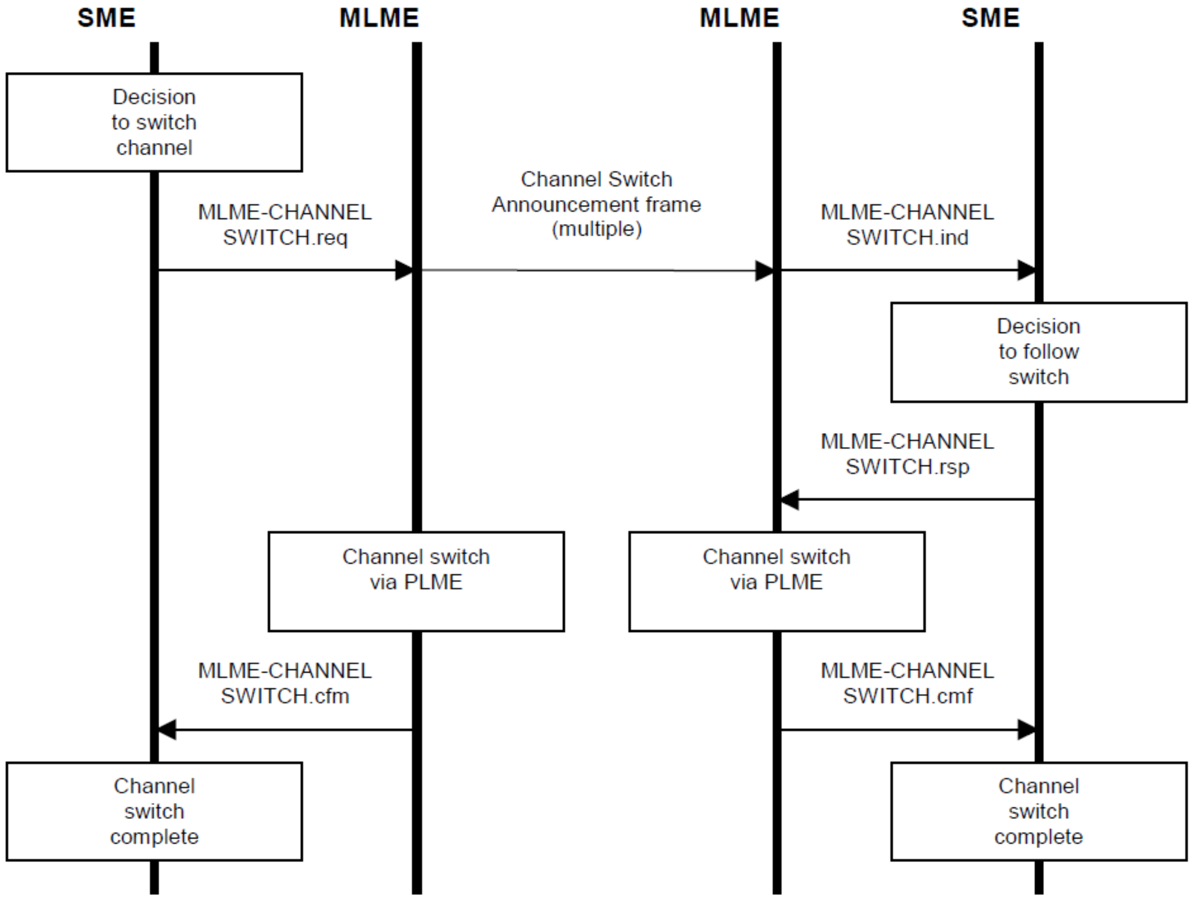
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 13 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

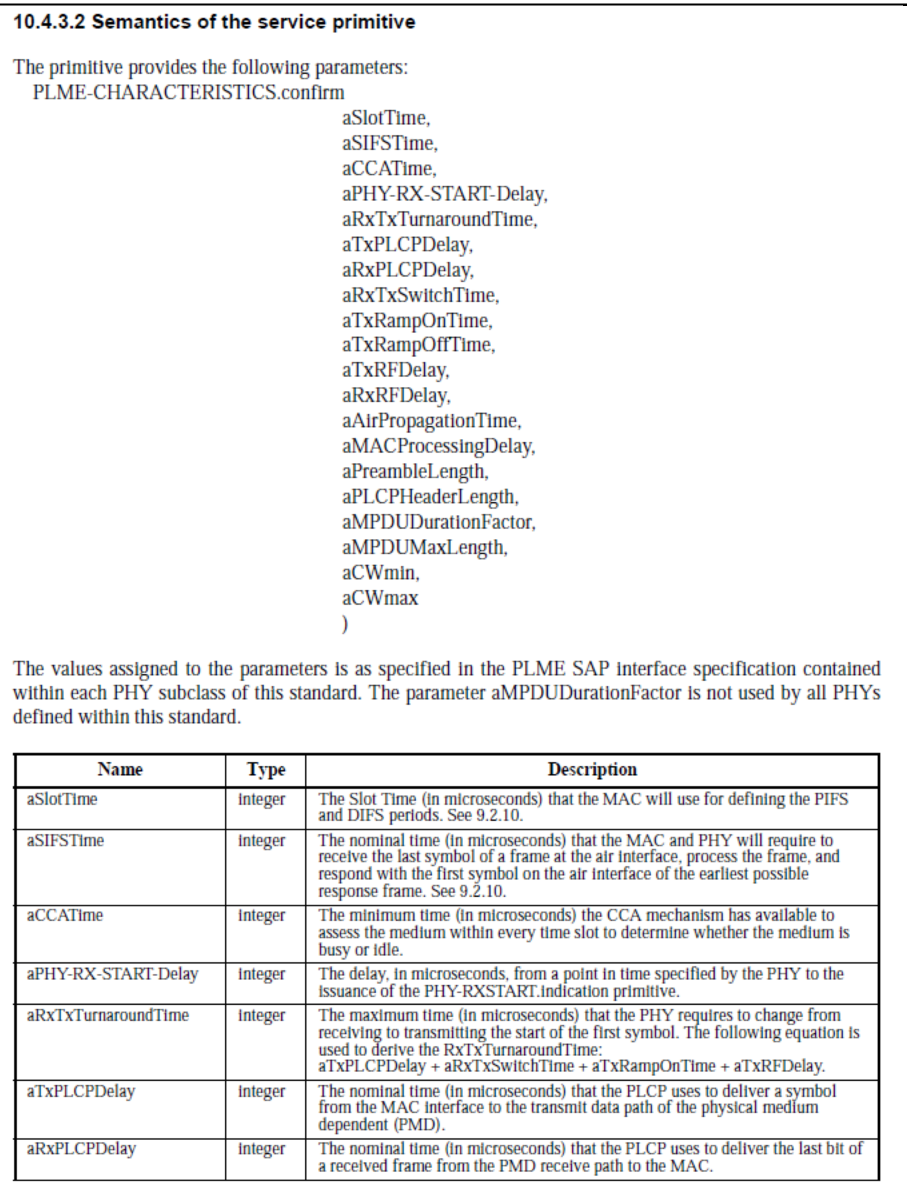
Claim 13 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
[14.1] The method of claim 10	802.11-2007 discloses all the elements of claim 10 for all the reasons provided above.
[14.2] wherein the second data is the same as the first data, the method further comprising:	802.11-2007 discloses “wherein the second data is the same as the first data, the method further comprising.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts**

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

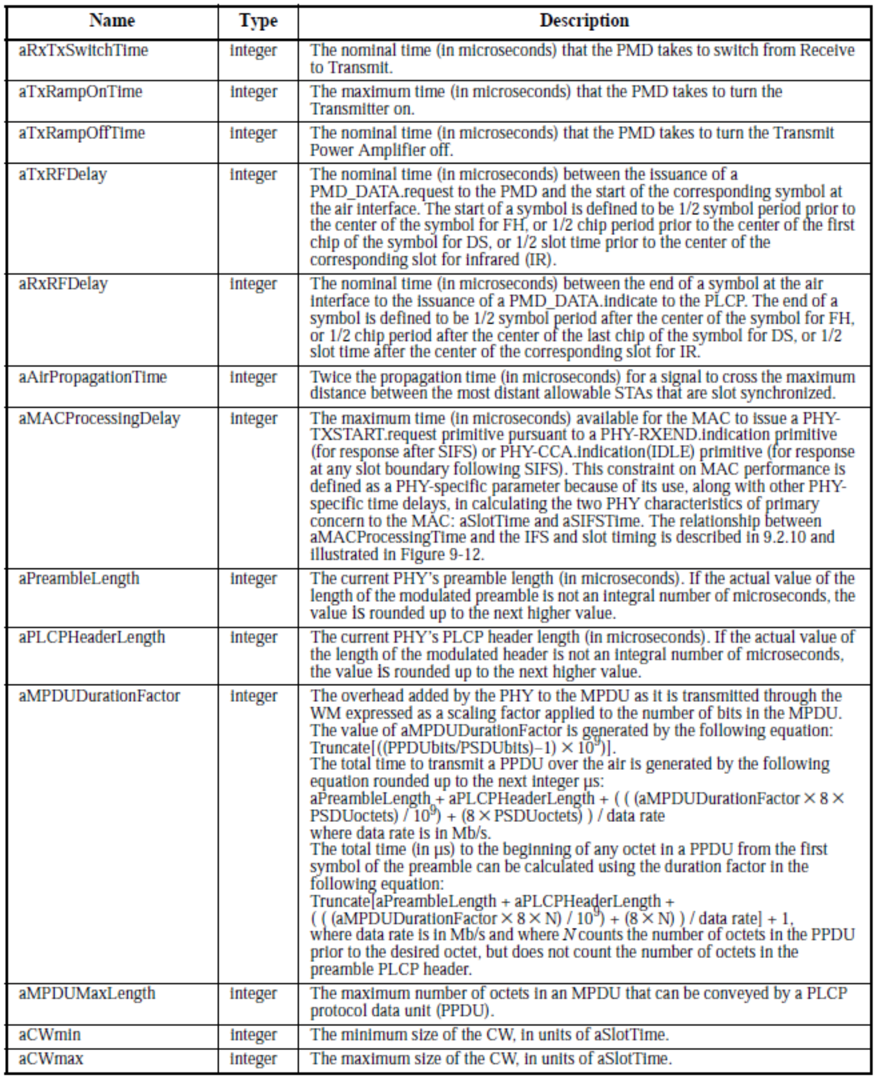
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007



Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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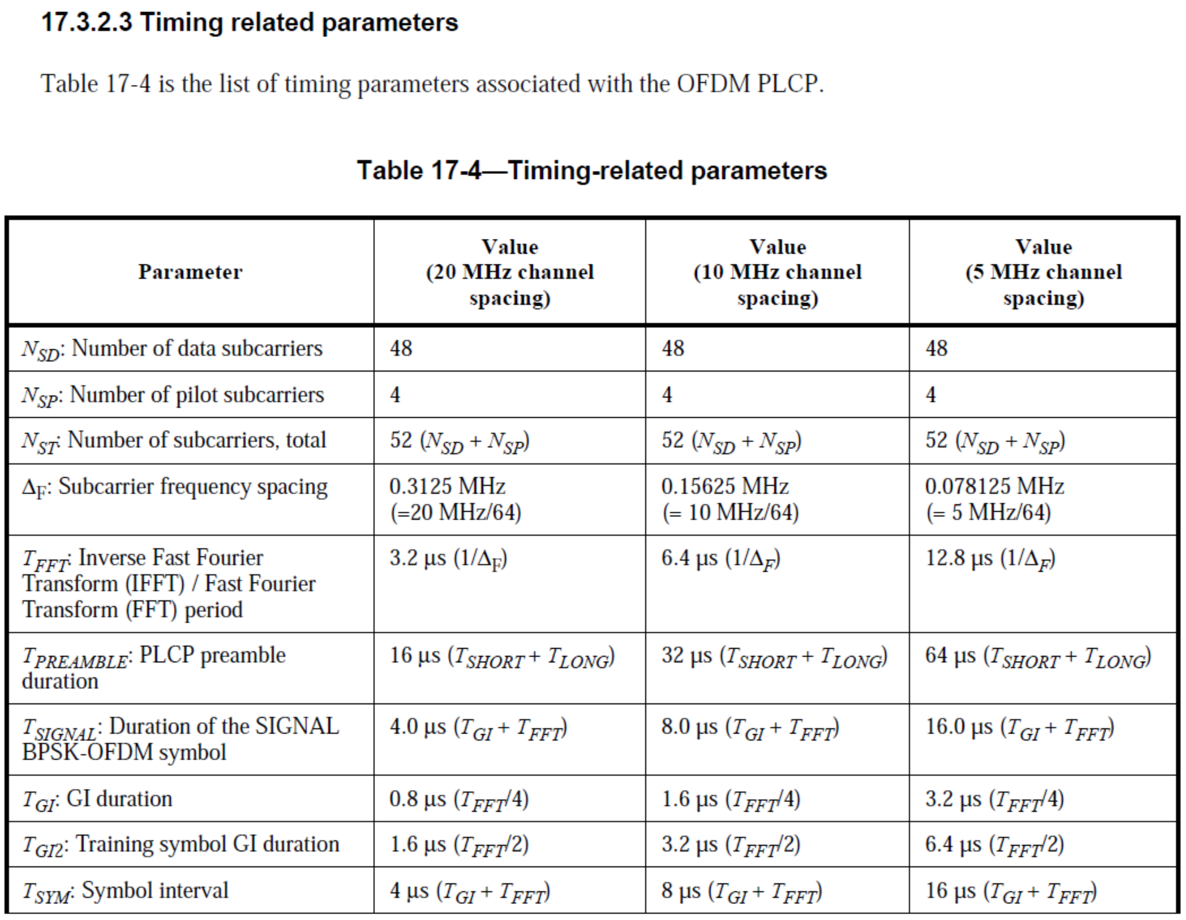
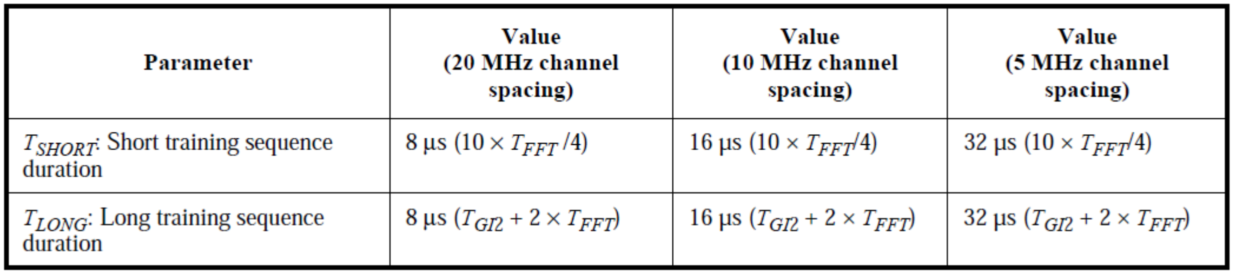


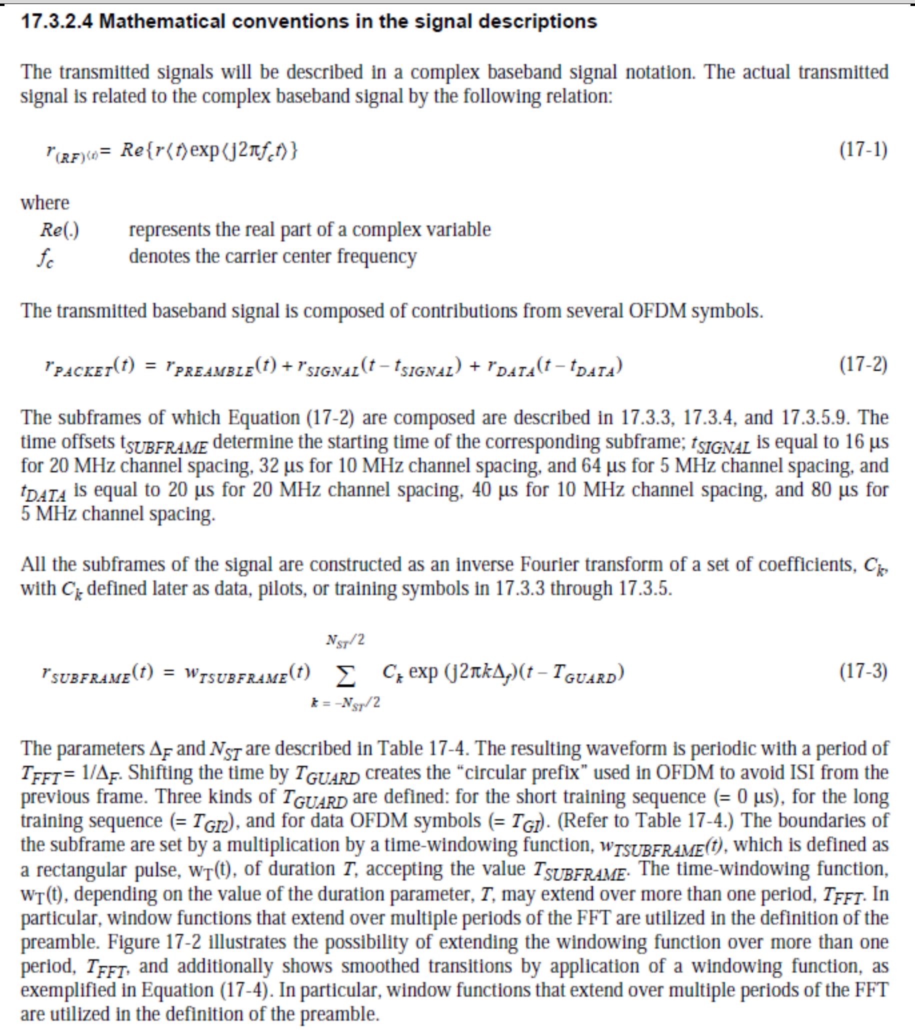
17.3.2.3 Timing related parameters

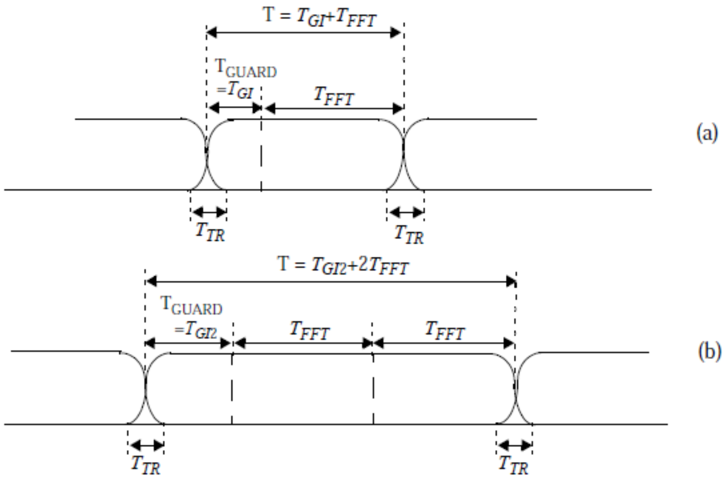
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

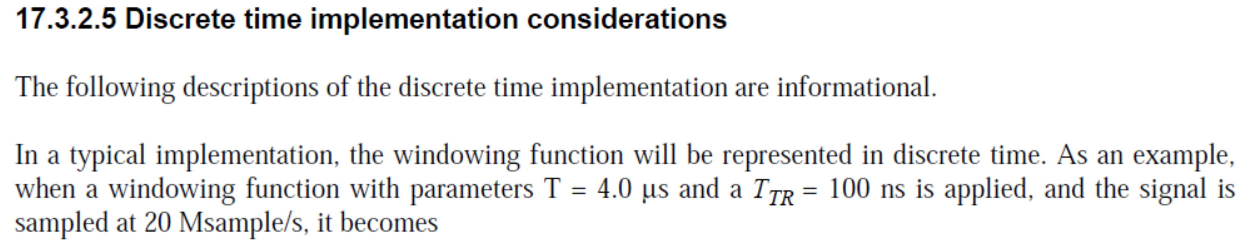
Table 17-4—Timing-related parameters

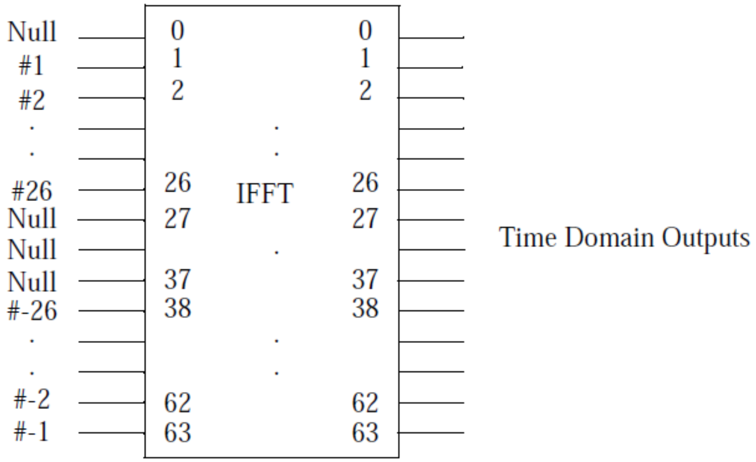
Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

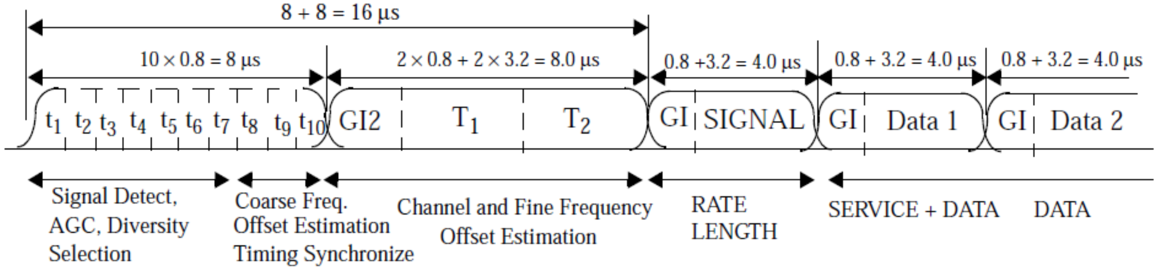
<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

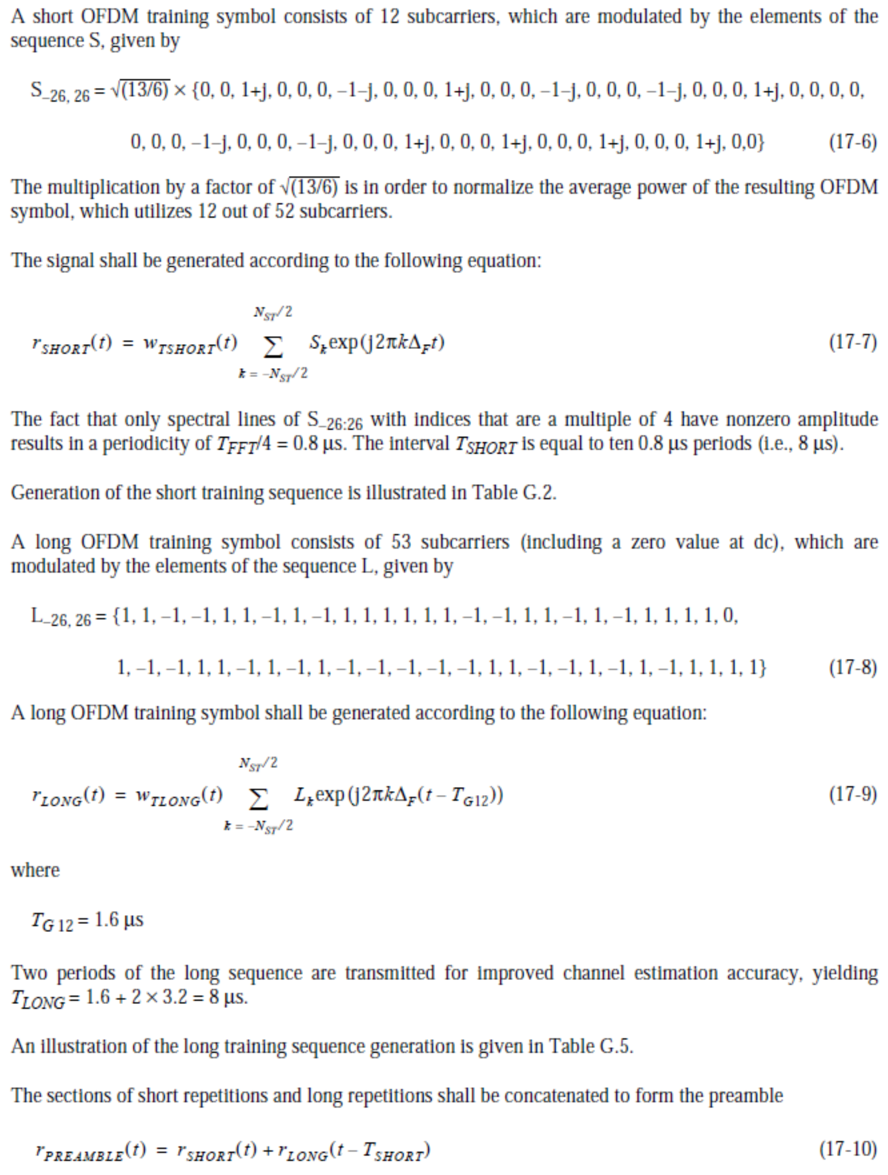
Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)(t)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{ \begin{matrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{matrix} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$
$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$
$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

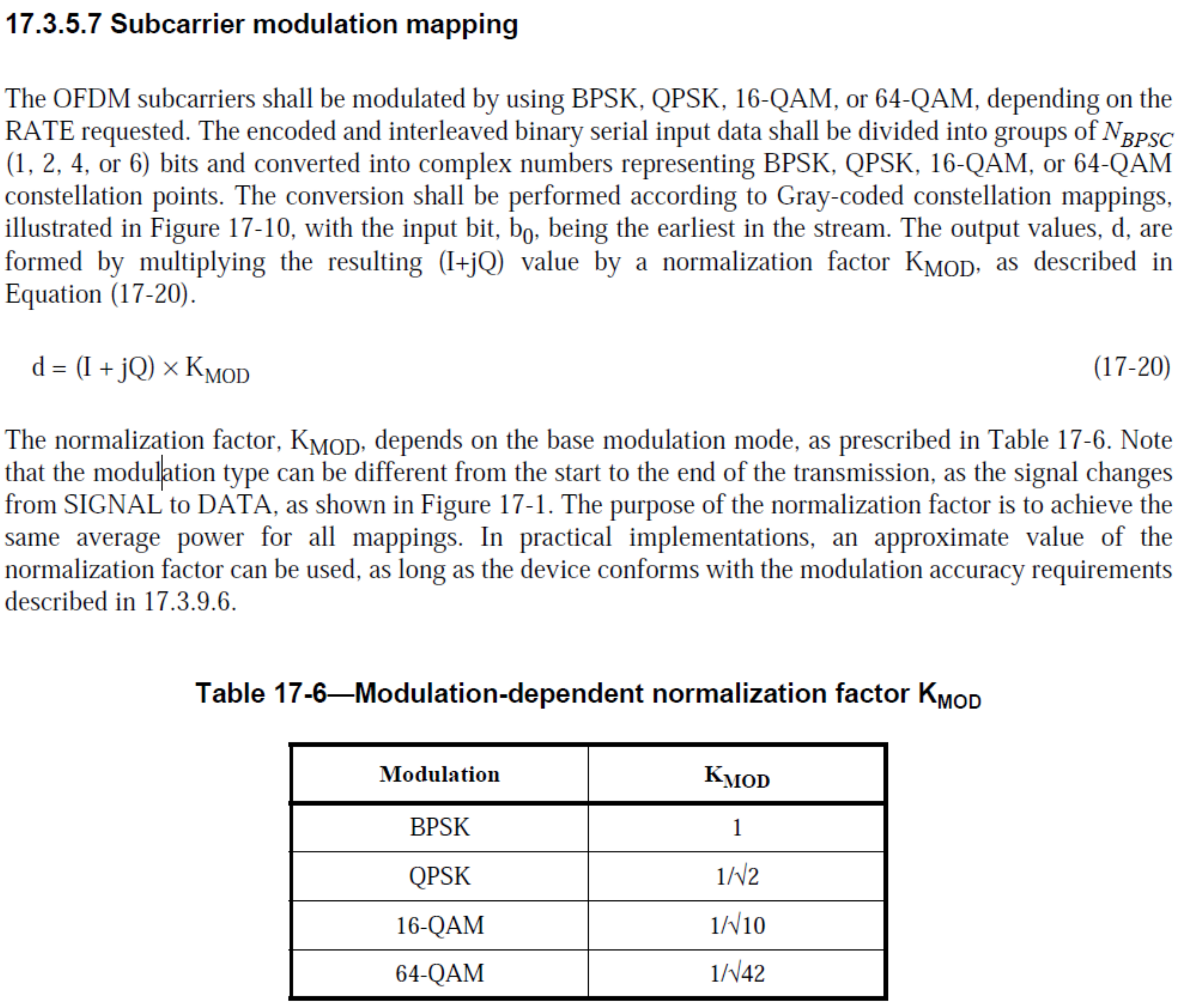
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \dots N_{SD} - 1,\ n = 0, \dots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,$$
$$1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,$$
$$-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,$$
$$-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

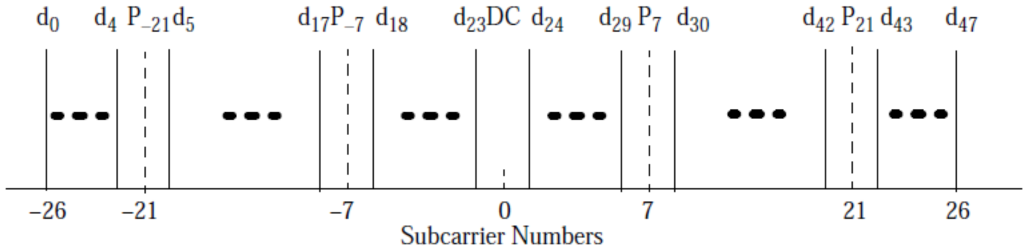


Figure 17-11—Subcarrier frequency allocation

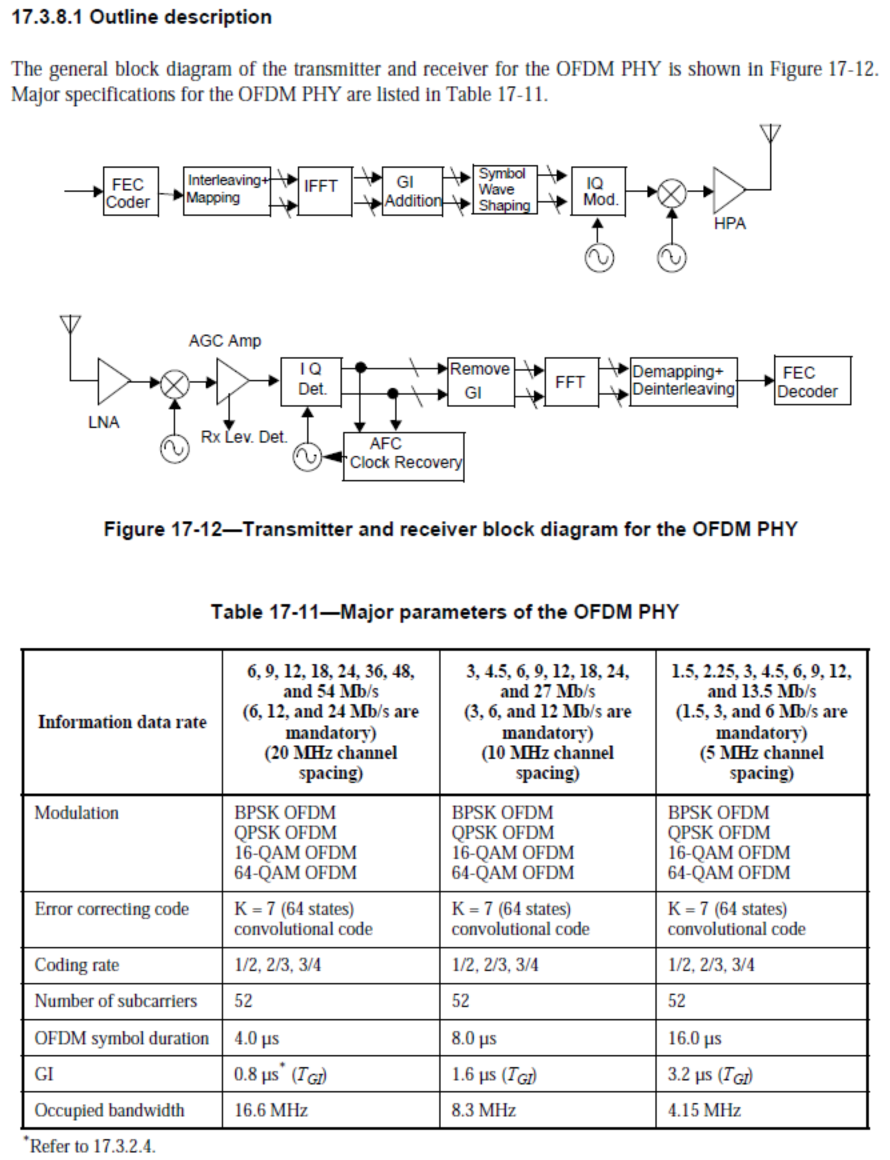
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs[*] (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

[*] Refer to 17.3.2.4.

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	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

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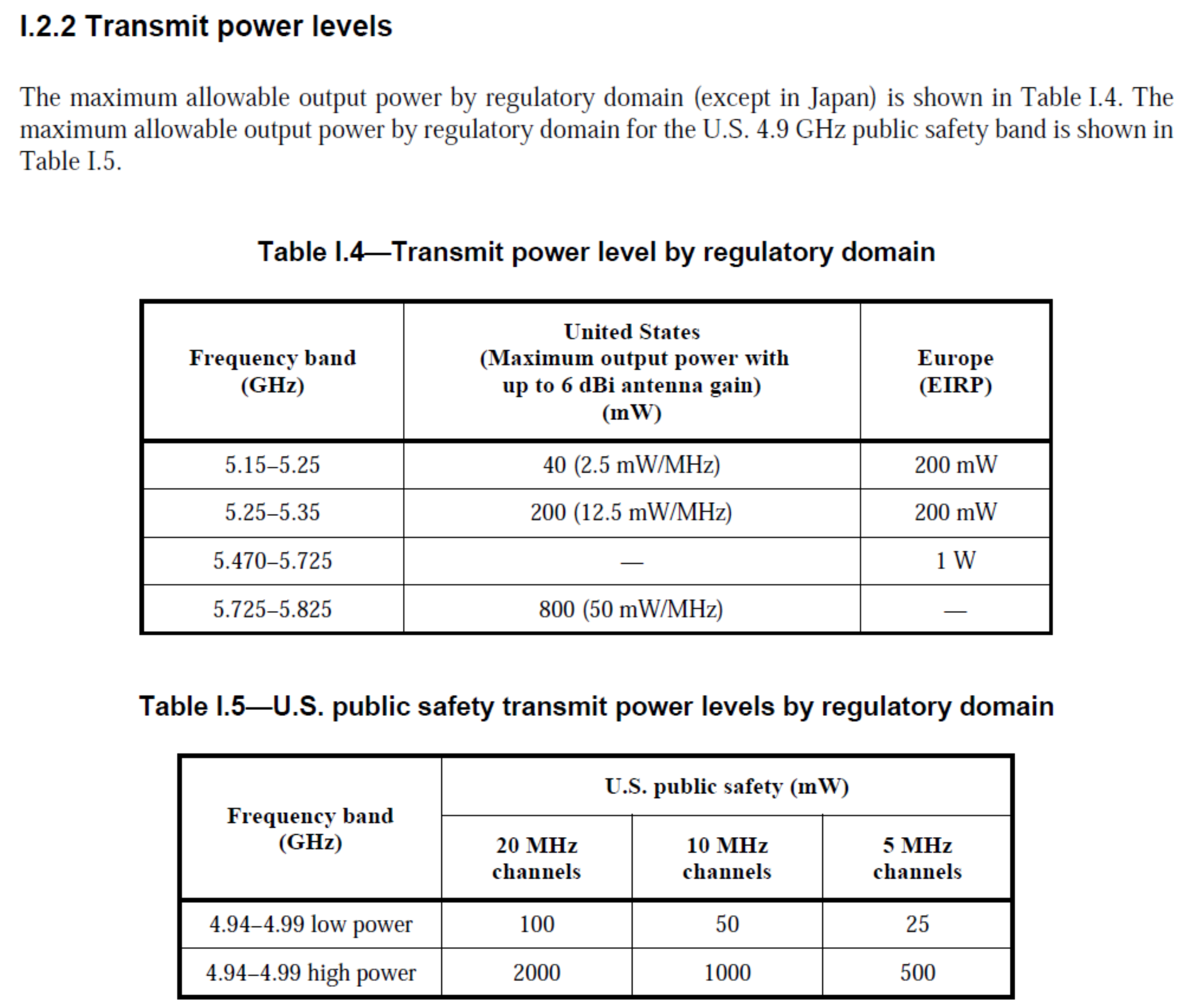

I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

Table I.4—Transmit power level by regulatory domain

Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

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	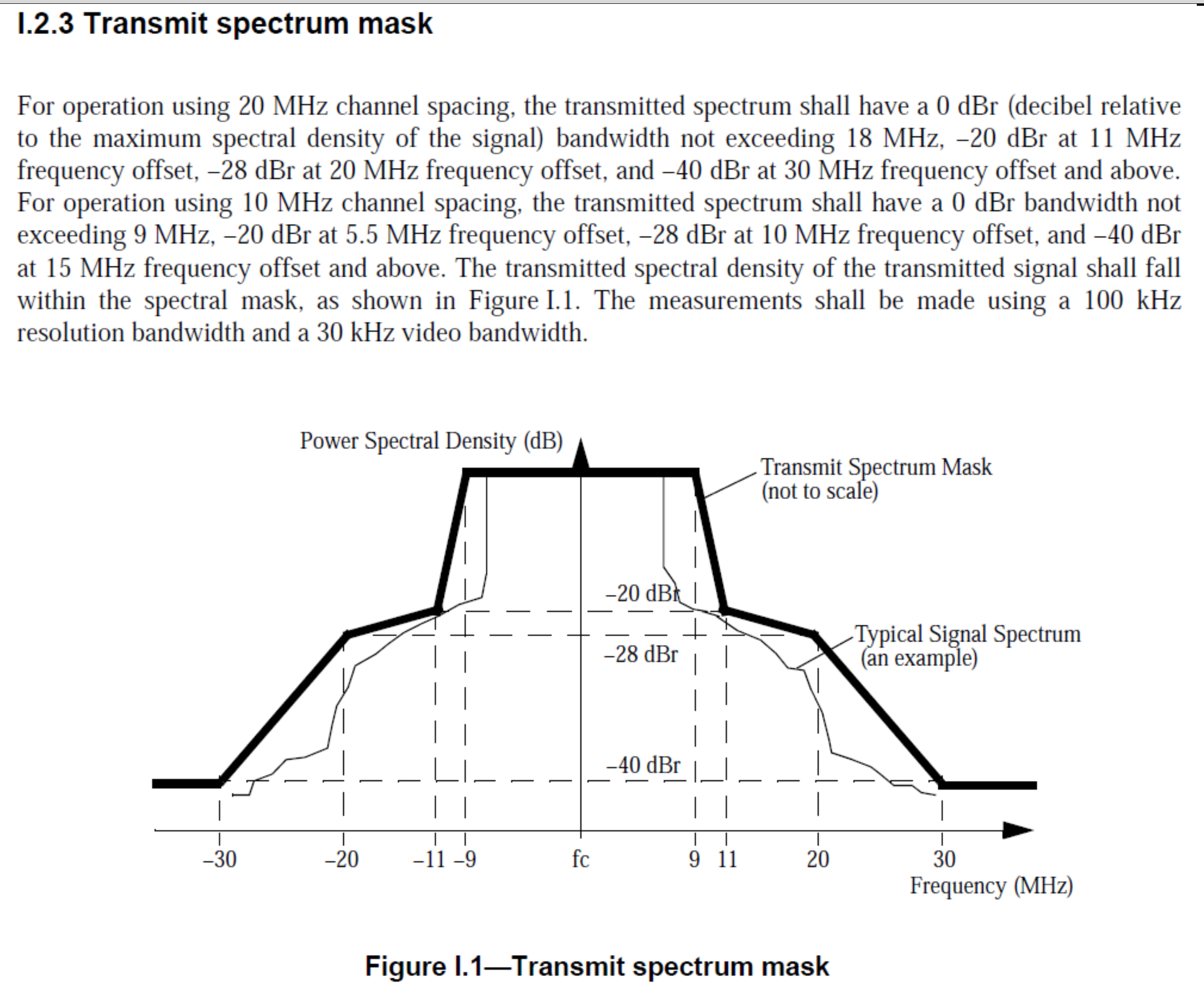 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

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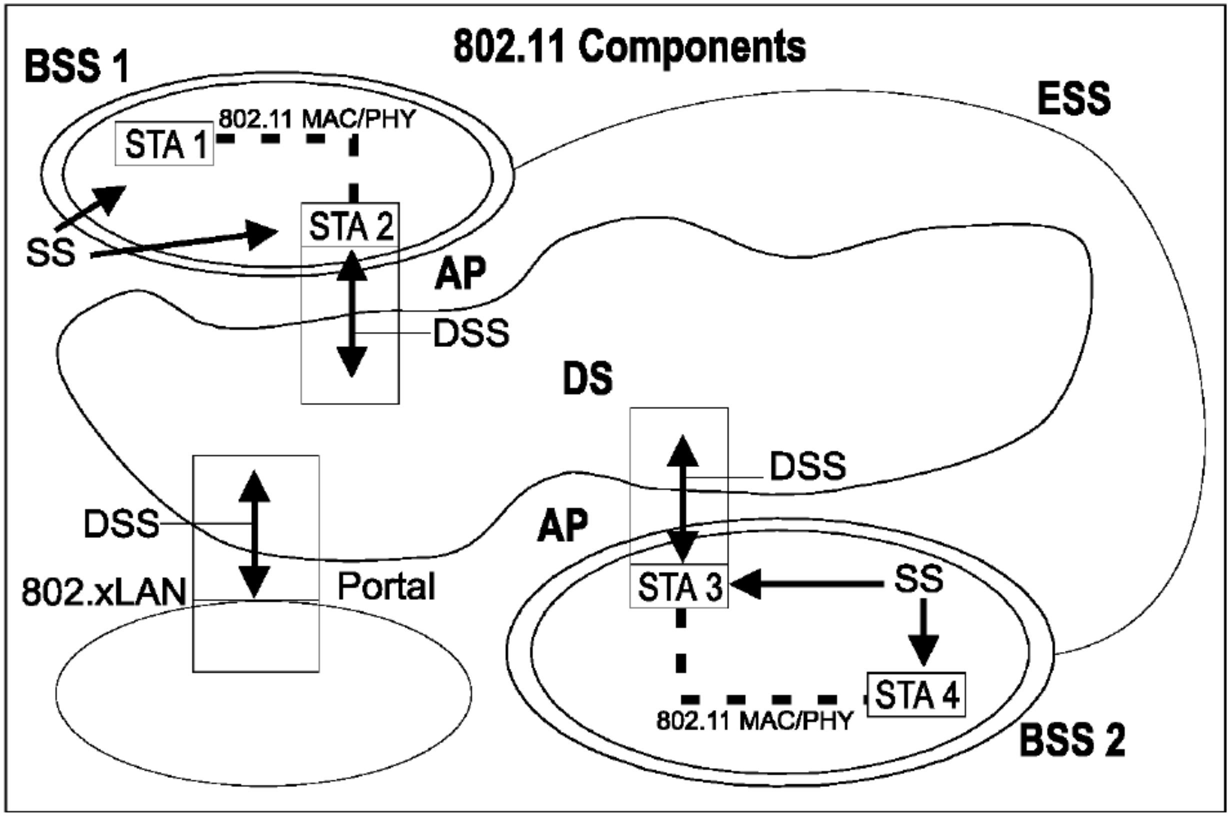
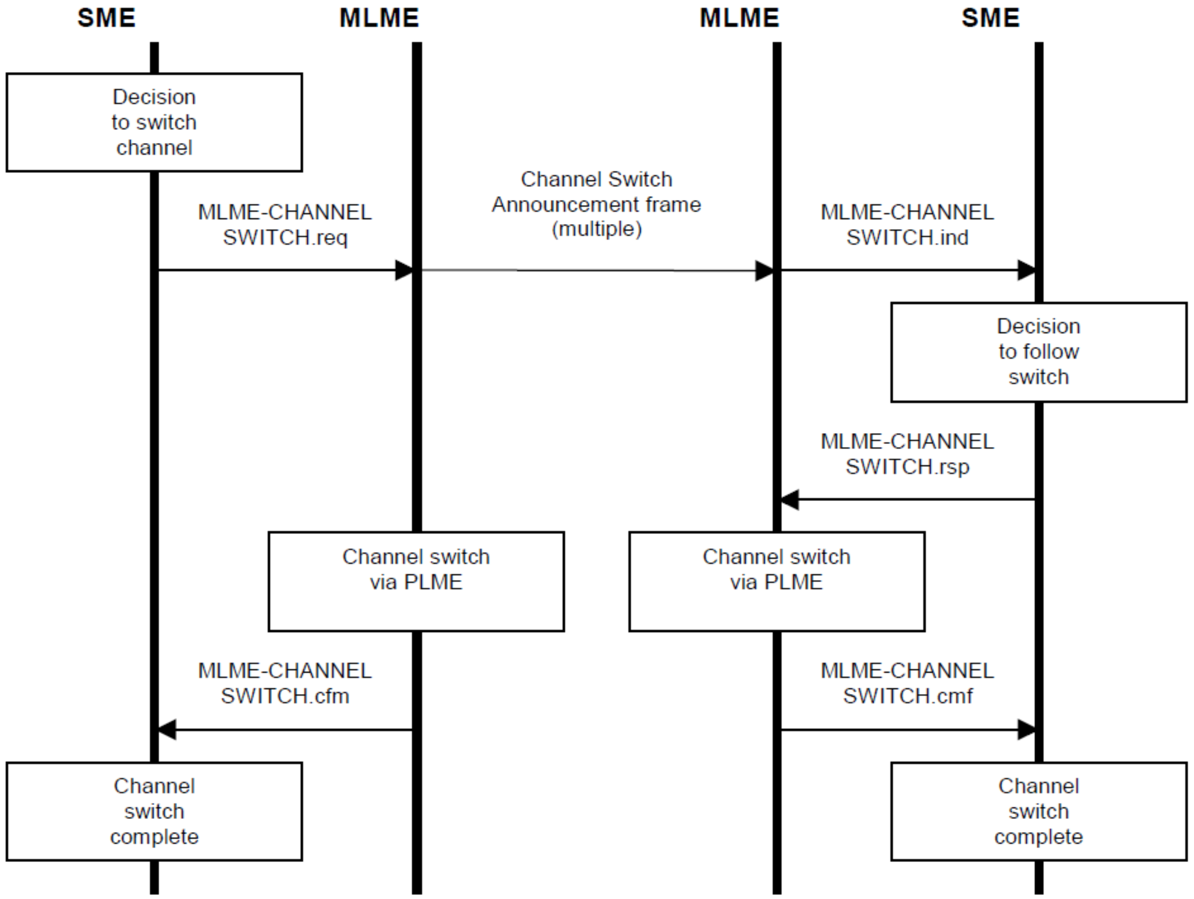
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[14.3] receiving the transmitted signal on a second antenna;	802.11-2007 discloses "receiving the transmitted signal on a second antenna." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood

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	that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11

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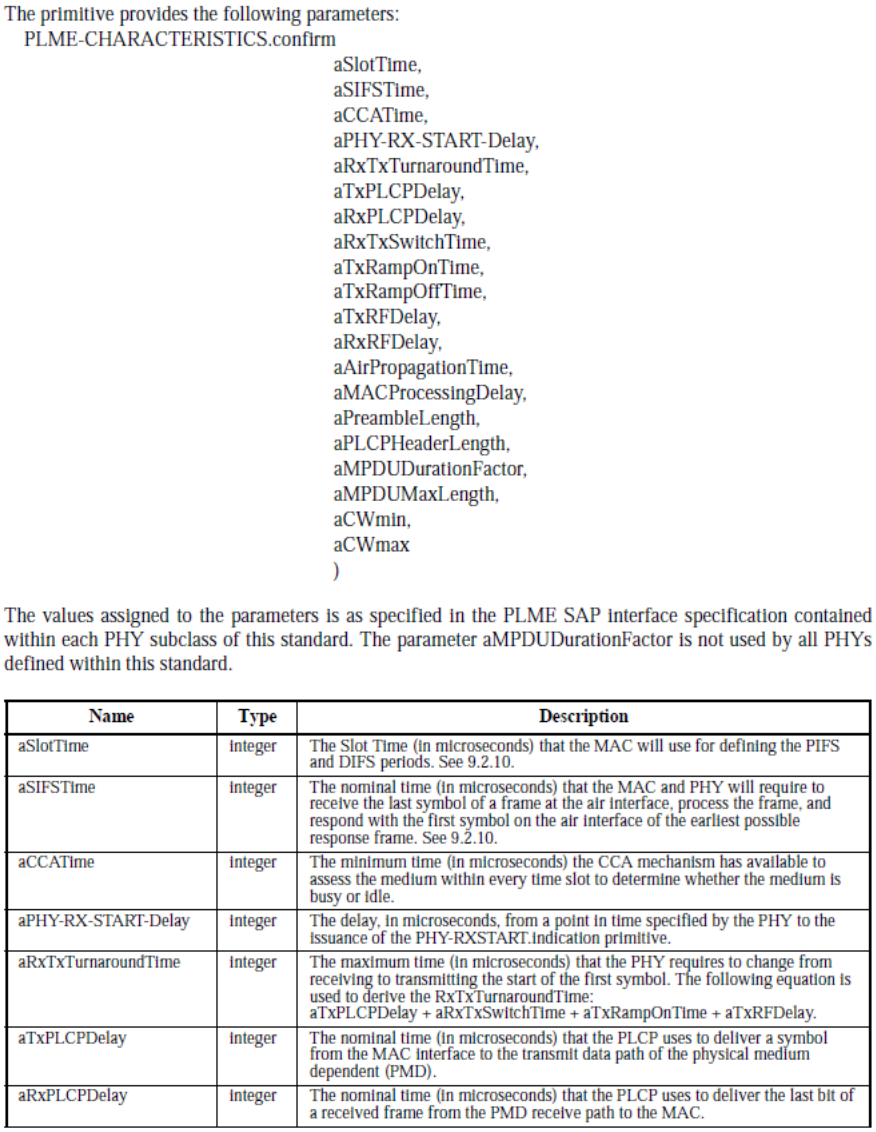
	definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	— Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive



The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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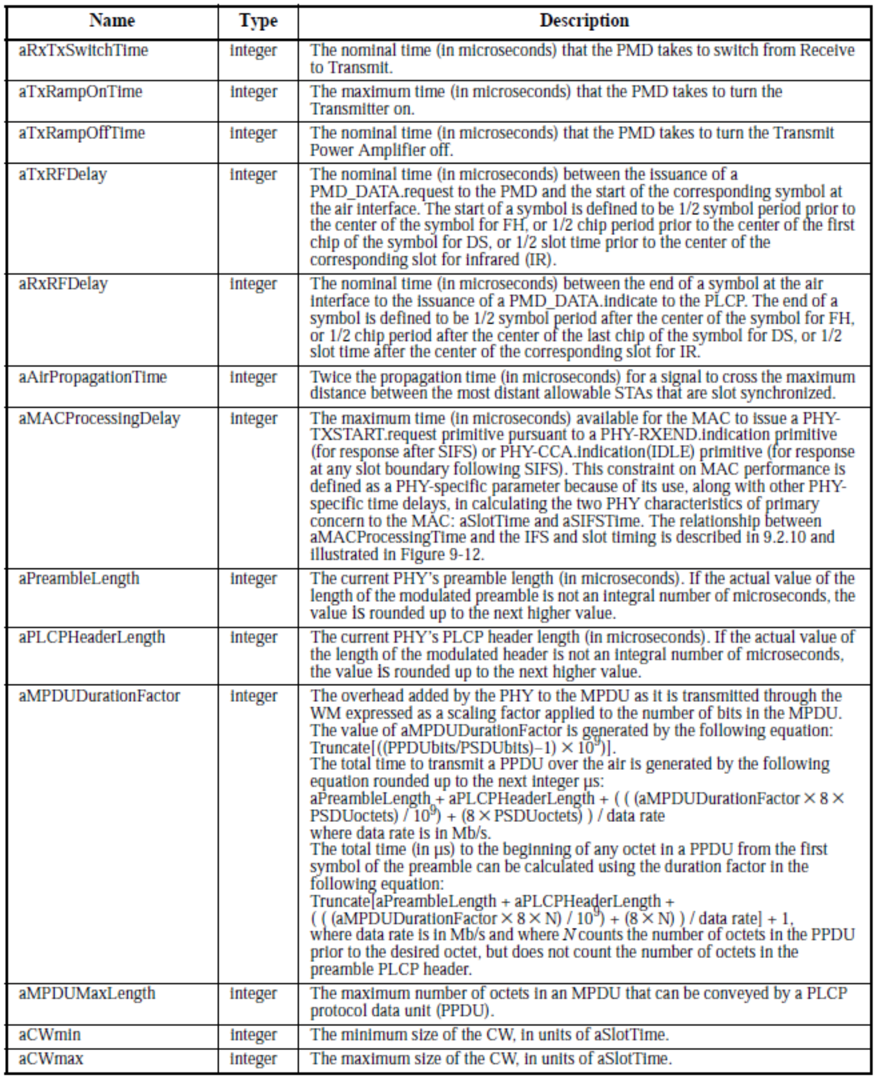

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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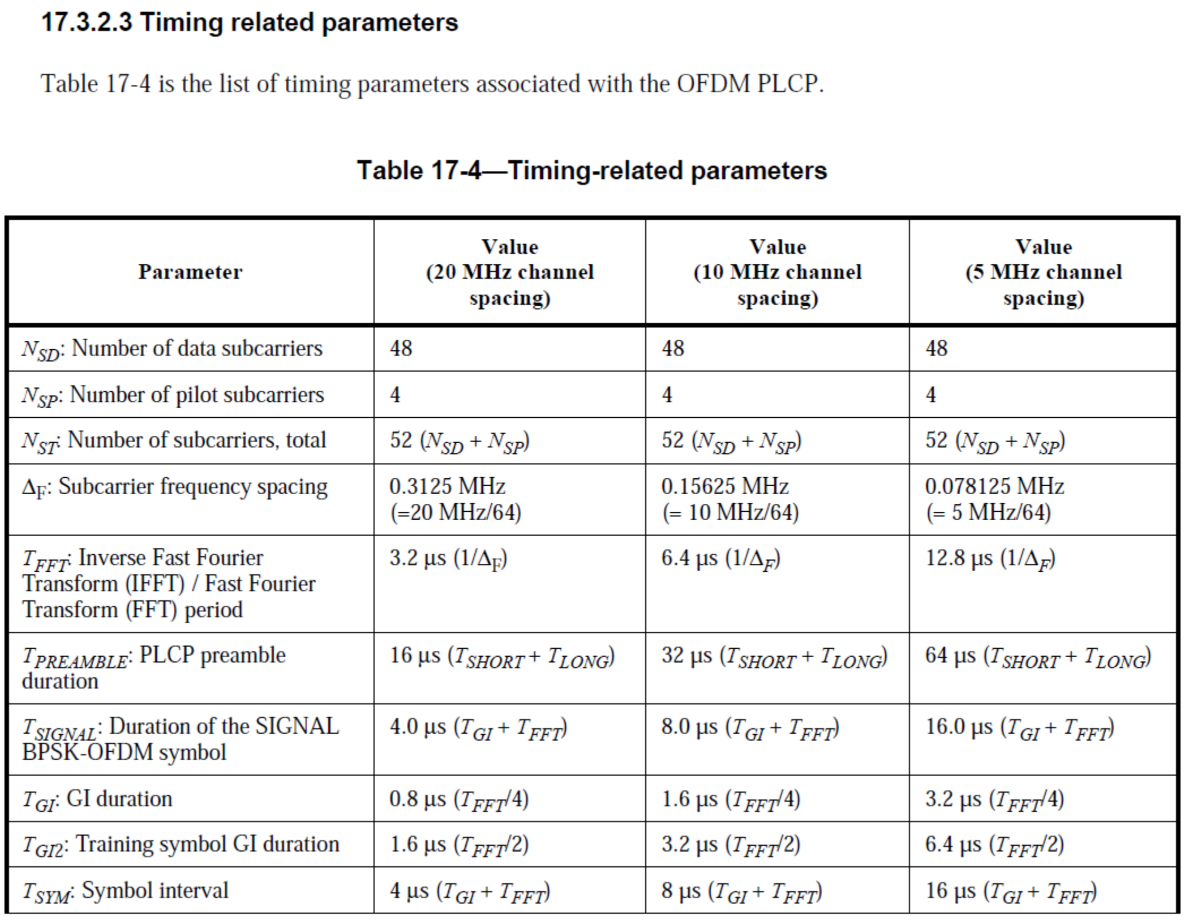
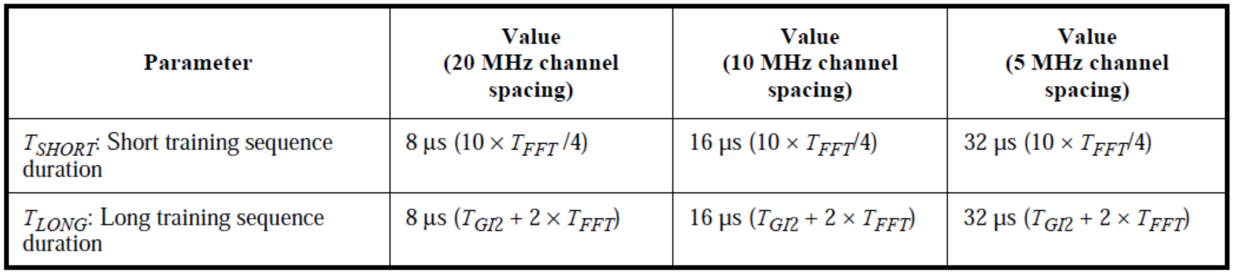
	

17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

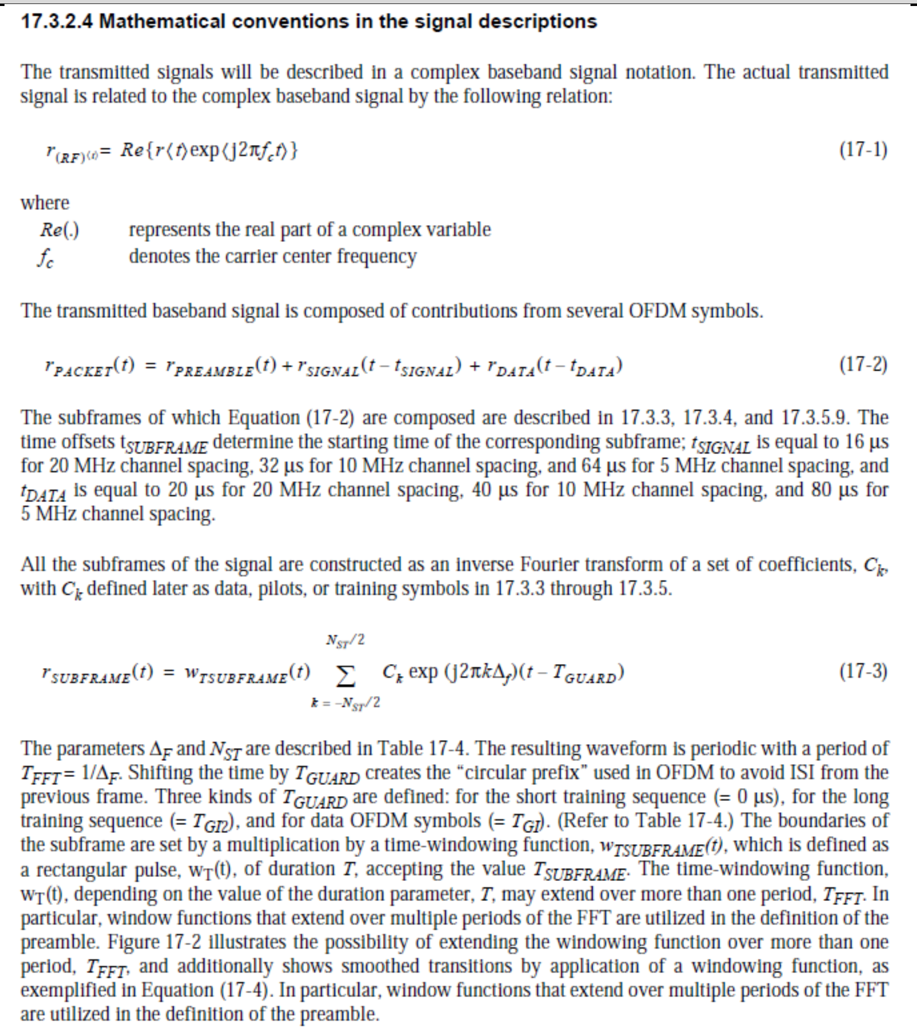
Table 17-4—Timing-related parameters

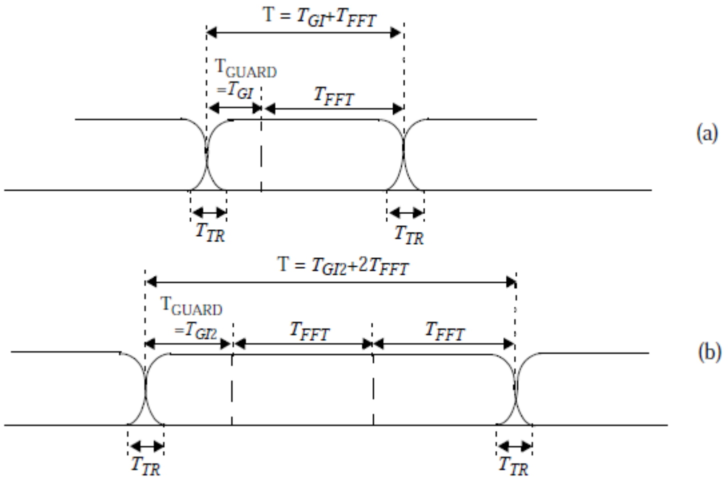
Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

$$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0,\ 80 \\ 0 & otherwise \end{cases} \qquad (17\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

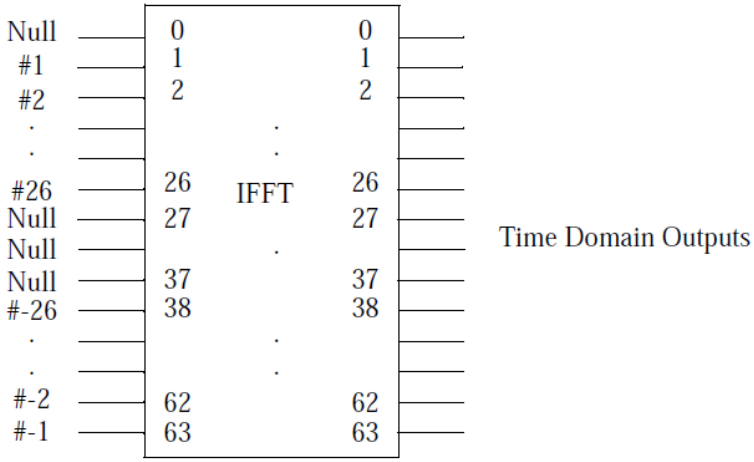
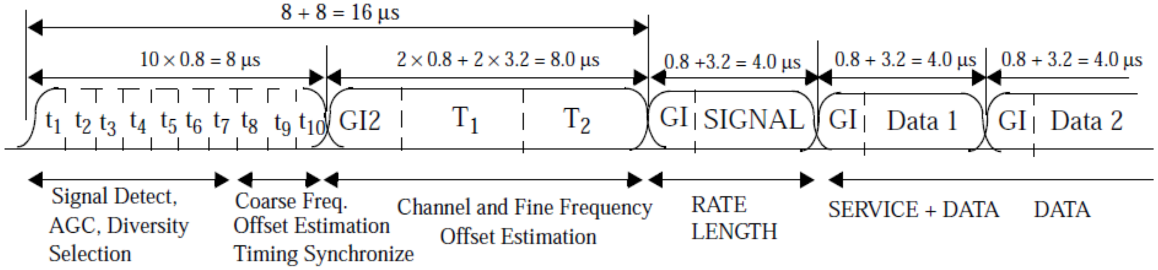
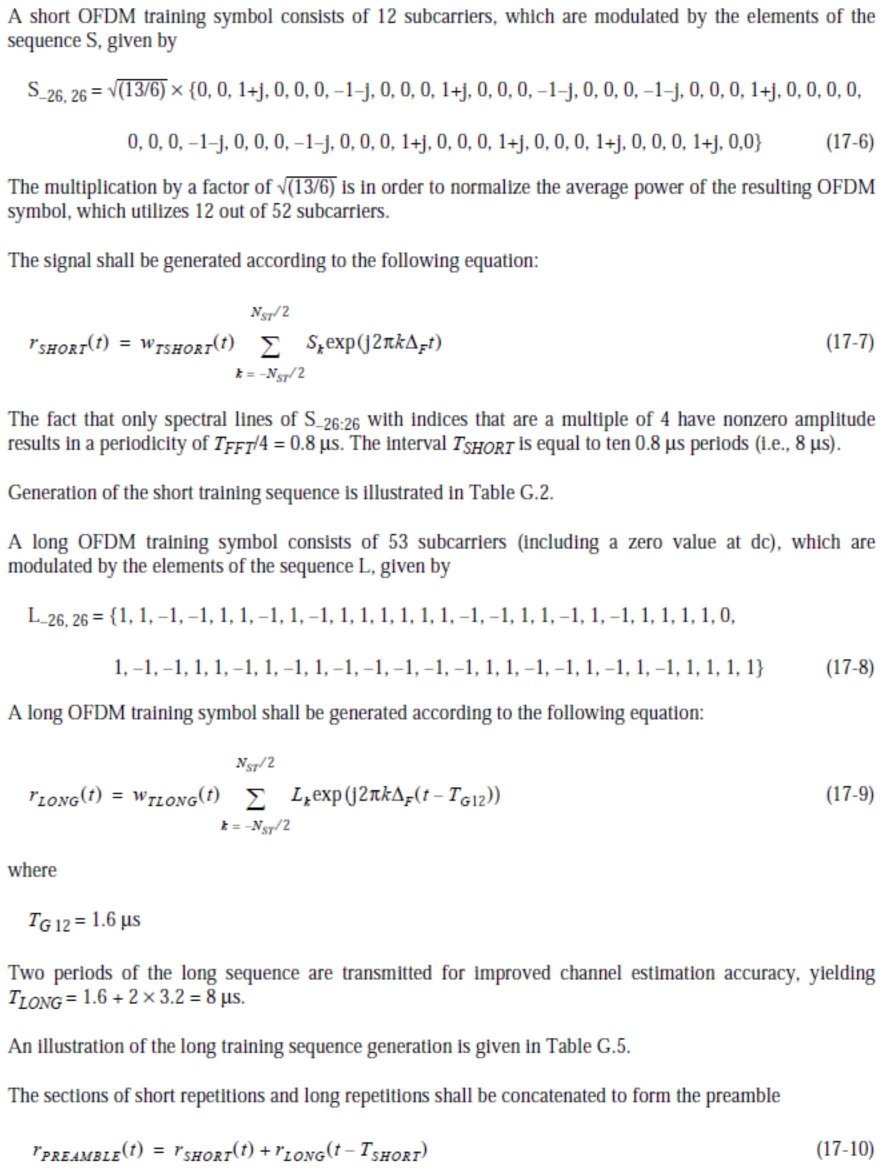


Figure 17-3—Inputs and outputs of inverse Fourier transform

See, e.g., 802.11-2007 § 17.3.2.5

</td></tr>
</table>

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, \\ 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, \\ 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F(t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

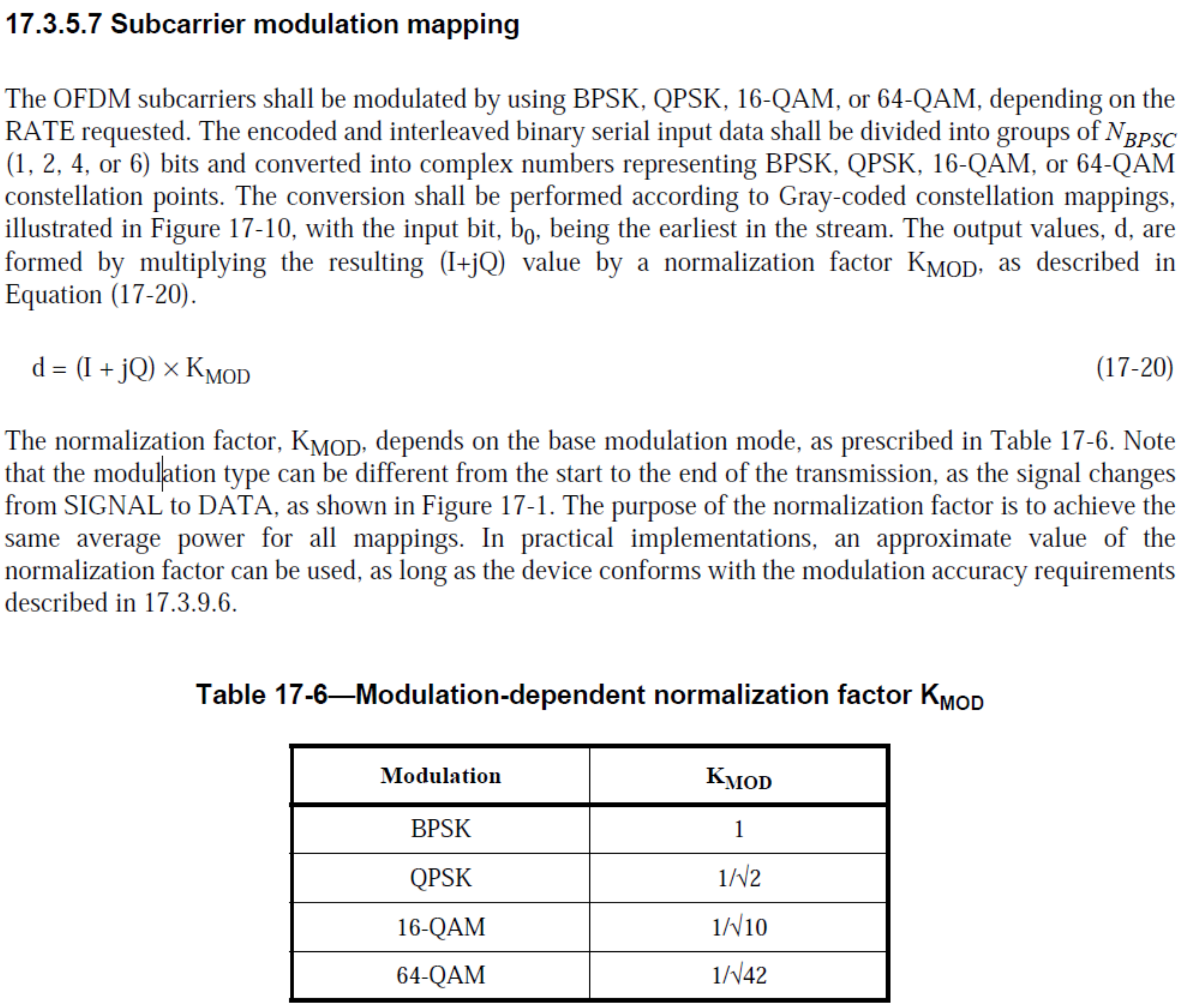
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}\,, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the nth OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$P_{-26,\,26} = \{0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1, \\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1, \\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1, \\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \tag{17-25}$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

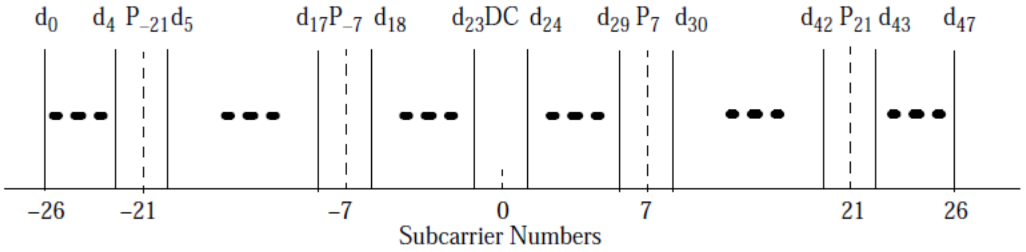


Figure 17-11—Subcarrier frequency allocation

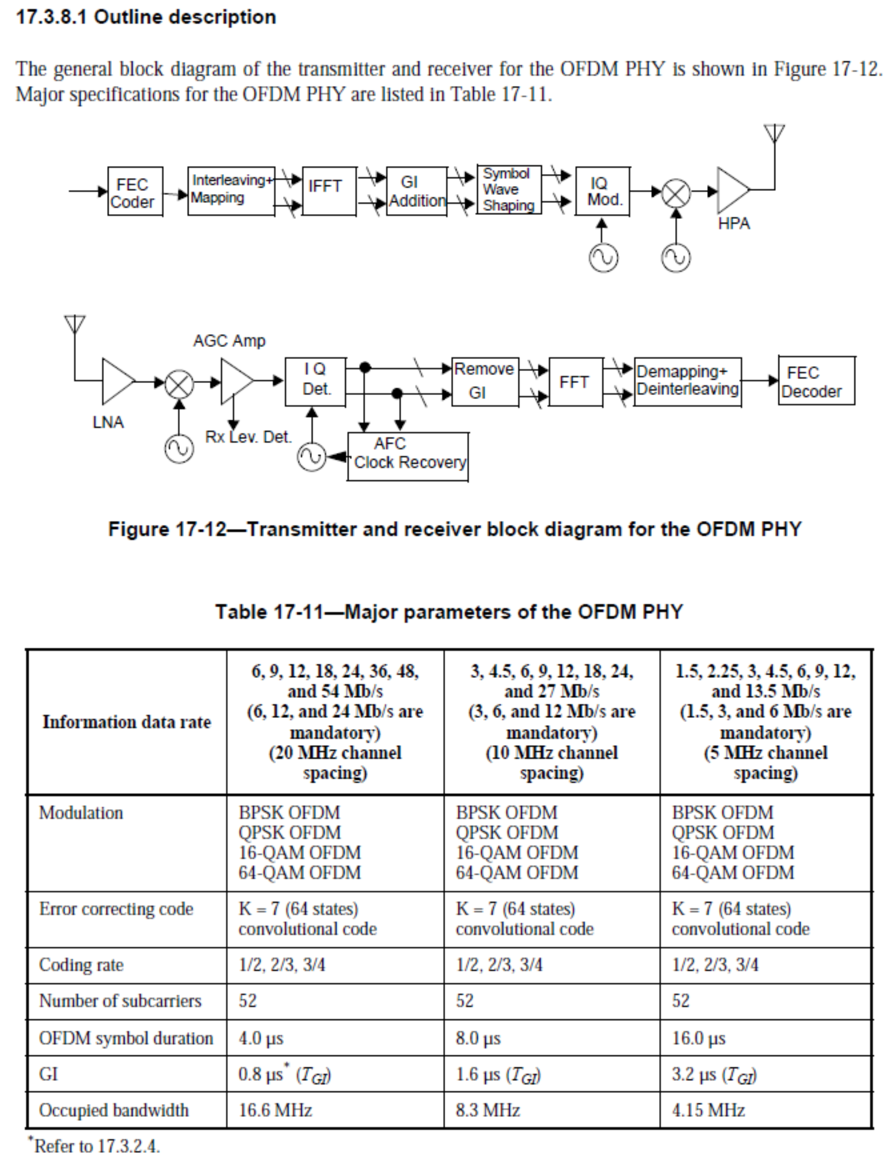
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \tag{17-26}$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

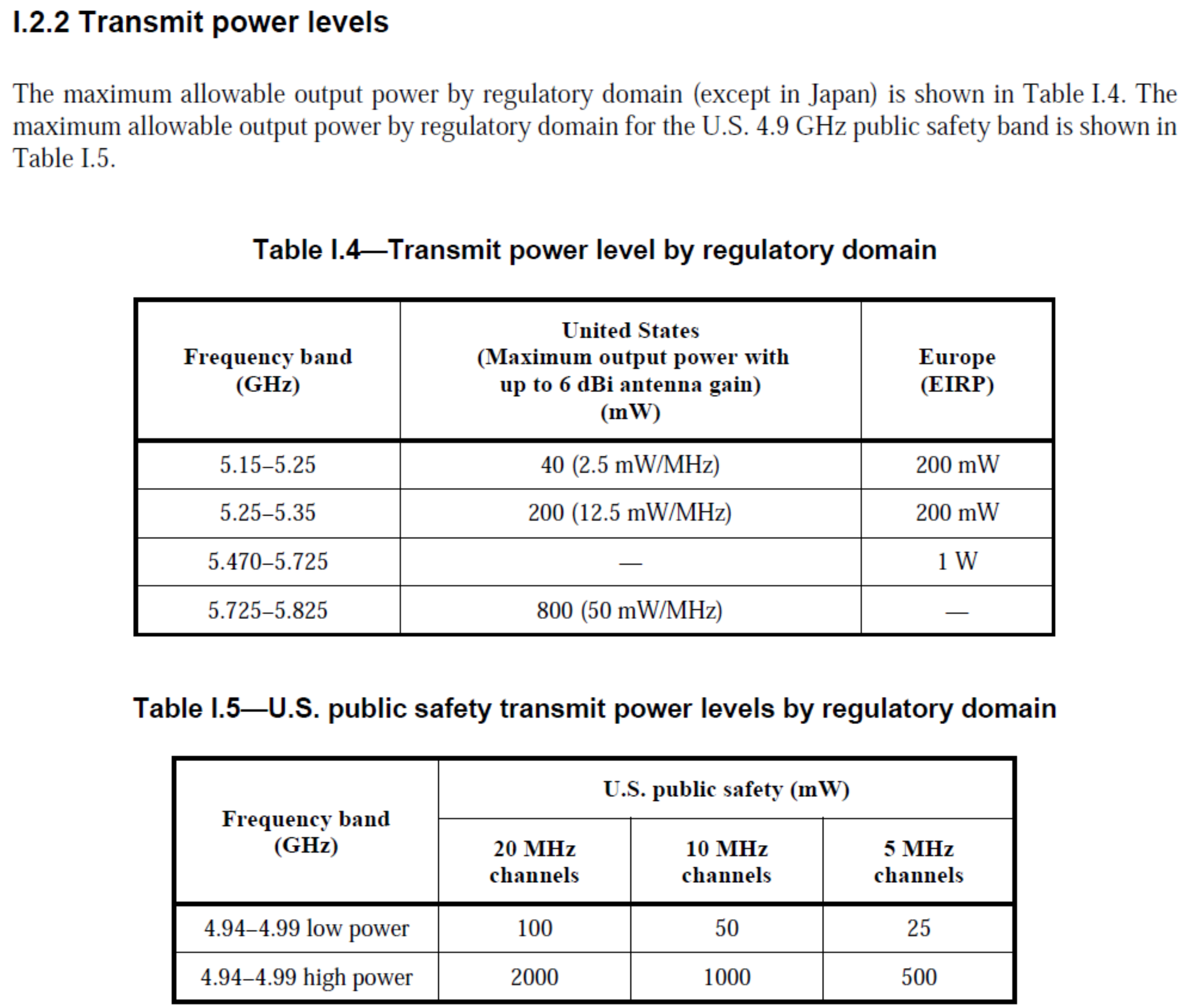
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

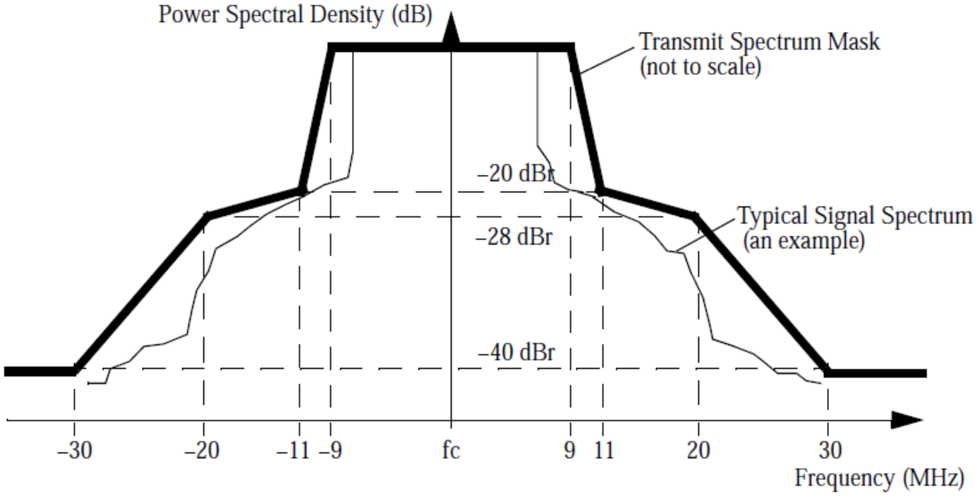
Table I.4—Transmit power level by regulatory domain

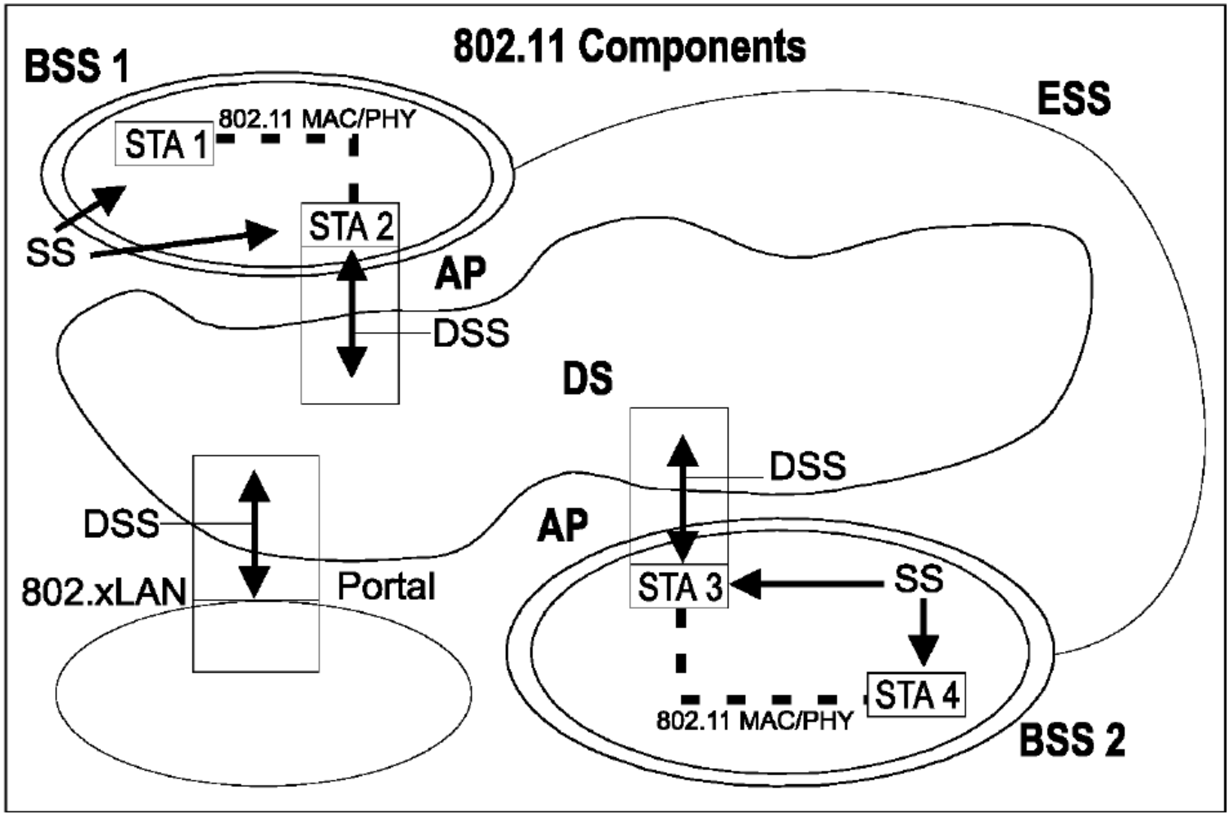
<table>
<tr><th>Frequency band (GHz)</th><th>United States (Maximum output power with up to 6 dBi antenna gain) (mW)</th><th>Europe (EIRP)</th></tr>
<tr><td>5.15–5.25</td><td>40 (2.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.25–5.35</td><td>200 (12.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.470–5.725</td><td>—</td><td>1 W</td></tr>
<tr><td>5.725–5.825</td><td>800 (50 mW/MHz)</td><td>—</td></tr>
</table>

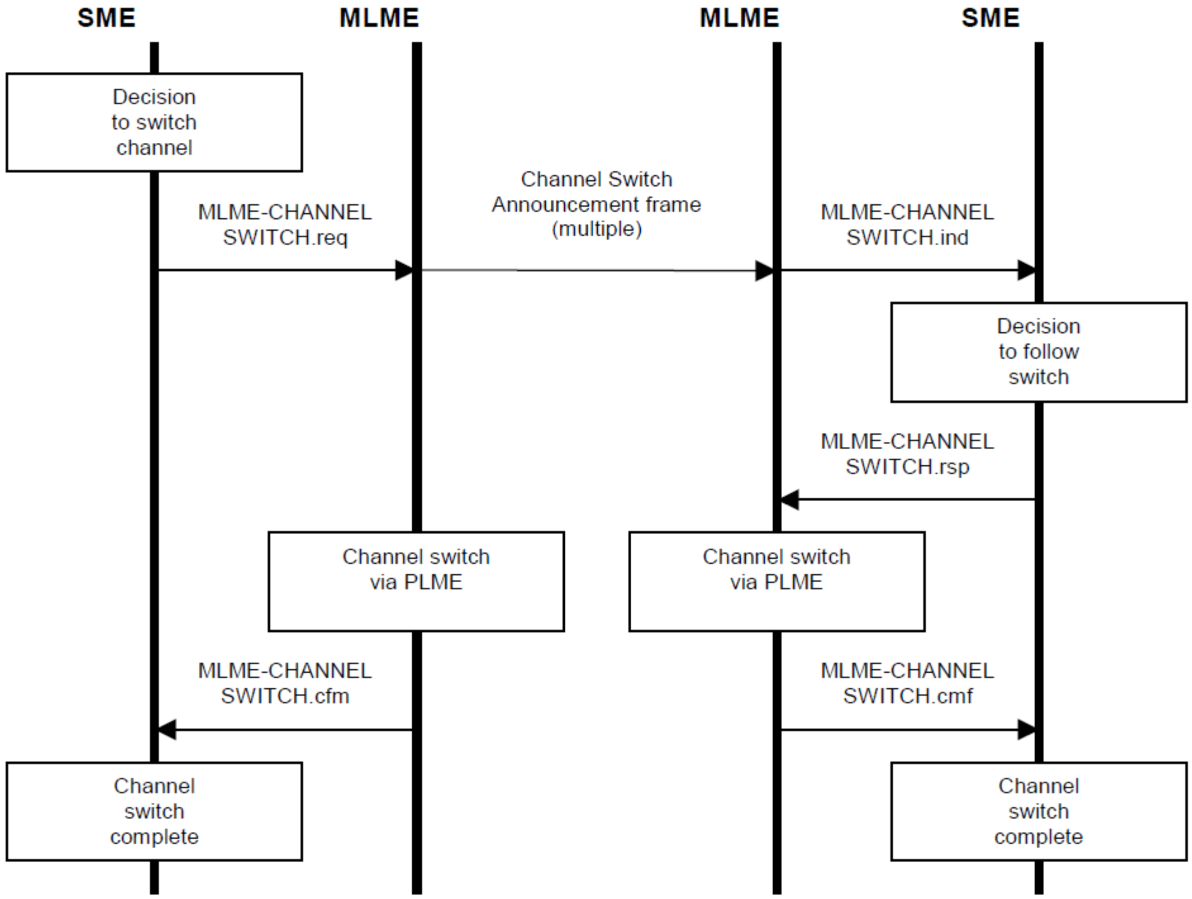
Table I.5—U.S. public safety transmit power levels by regulatory domain

<table>
<tr><th rowspan="2">Frequency band (GHz)</th><th colspan="3">U.S. public safety (mW)</th></tr>
<tr><th>20 MHz channels</th><th>10 MHz channels</th><th>5 MHz channels</th></tr>
<tr><td>4.94–4.99 low power</td><td>100</td><td>50</td><td>25</td></tr>
<tr><td>4.94–4.99 high power</td><td>2000</td><td>1000</td><td>500</td></tr>
</table>

See, e.g., 802.11-2007 § I.2.2
</td></tr>
</table>

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[14.4] amplifying the received signal in a low noise amplifier resulting in an amplified received up-converted signal, wherein the bandwidth of said low noise amplifier is greater than the difference between the lowest frequency in the first up-converted frequency range and the highest frequency in the second up-converted frequency range;	802.11-2007 discloses “amplifying the received signal in a low noise amplifier resulting in an amplified received up-converted signal, wherein the bandwidth of said low noise amplifier is greater than the difference between the lowest frequency in the first up-converted frequency range and the highest frequency in the second up-converted frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

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	areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is

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	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

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	to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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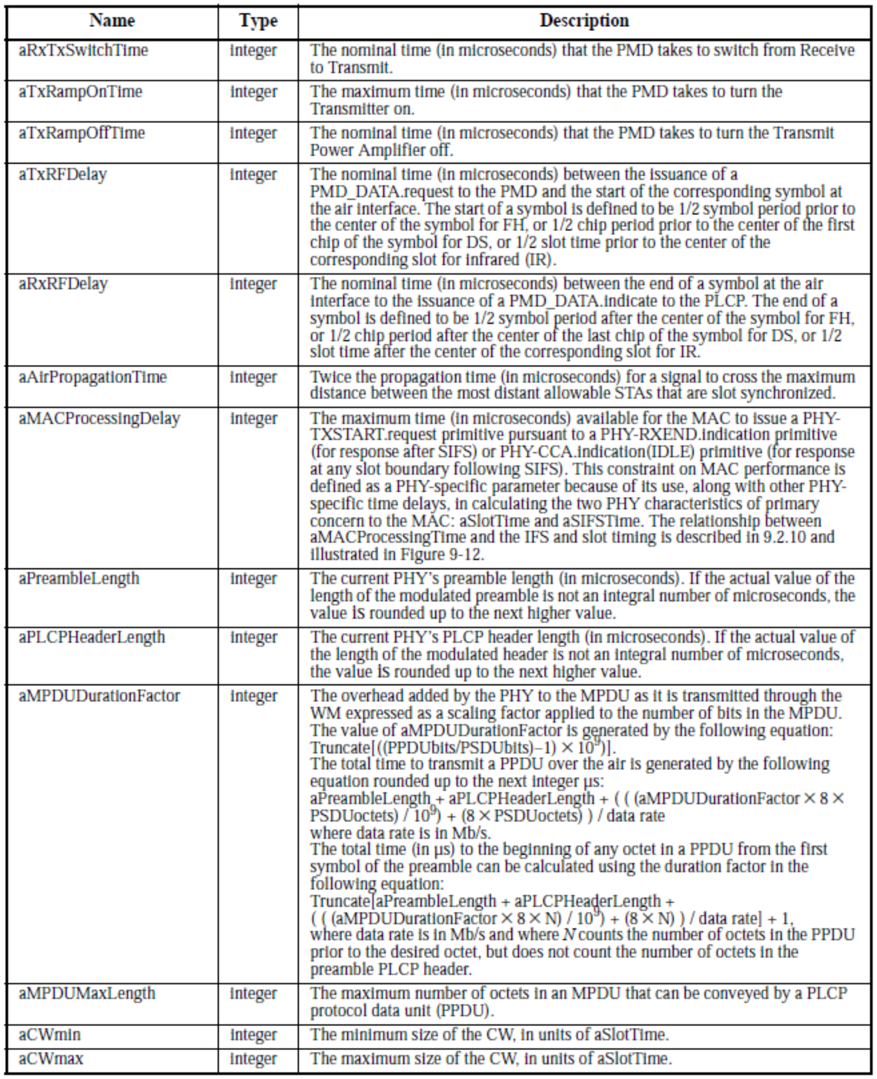

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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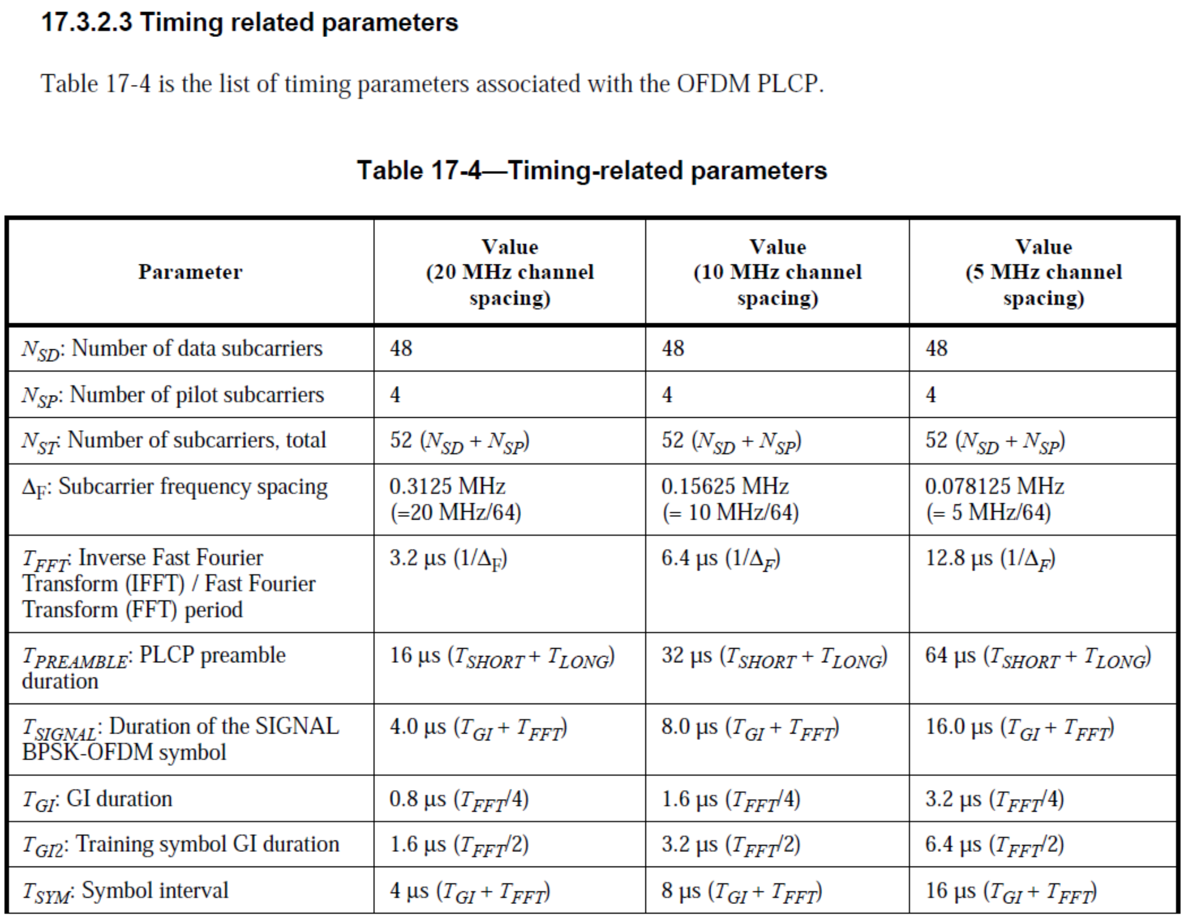
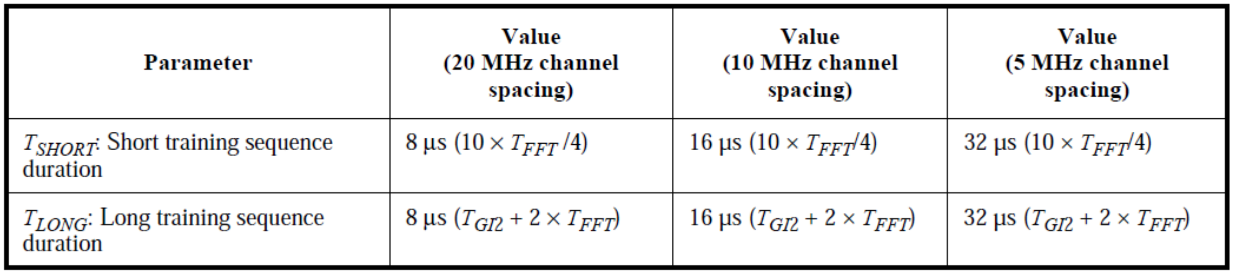


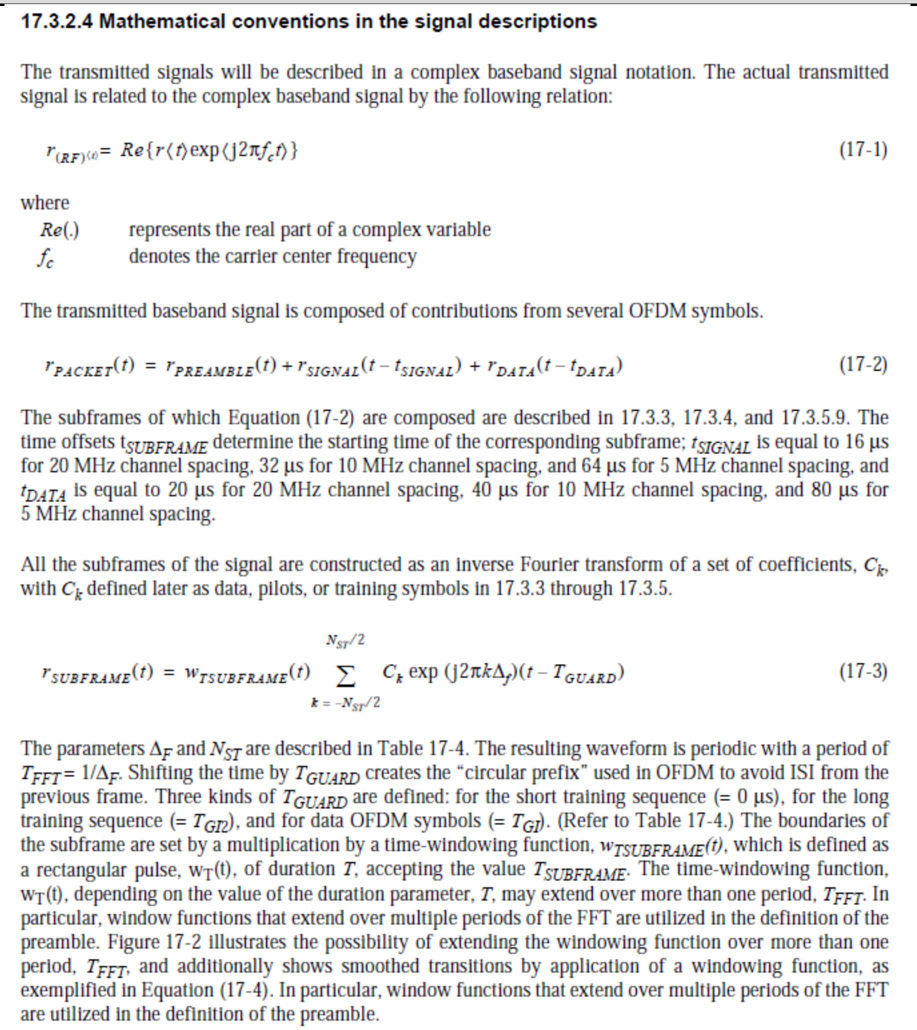
17.3.2.3 Timing related parameters

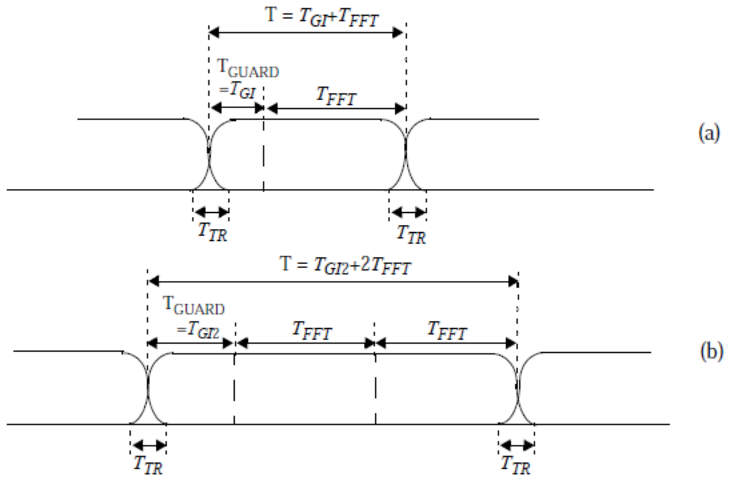
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

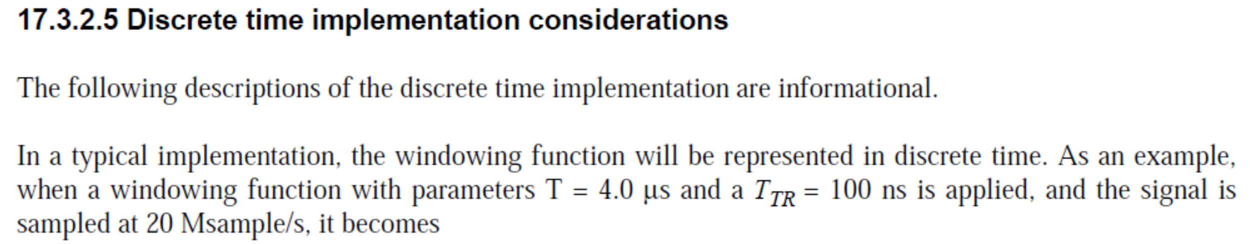
Table 17-4—Timing-related parameters

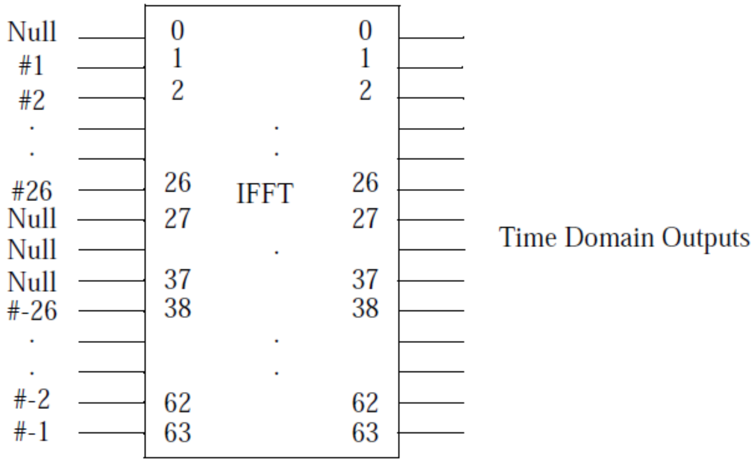
Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs ($10 \times T_{FFT}/4$)</td><td>16 µs ($10 \times T_{FFT}/4$)</td><td>32 µs ($10 \times T_{FFT}/4$)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs ($T_{GI2} + 2 \times T_{FFT}$)</td><td>16 µs ($T_{GI2} + 2 \times T_{FFT}$)</td><td>32 µs ($T_{GI2} + 2 \times T_{FFT}$)</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 14 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T = 4.0$ μs and a $T_{TR} = 100$ ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \qquad (17\text{-}5)$$ The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

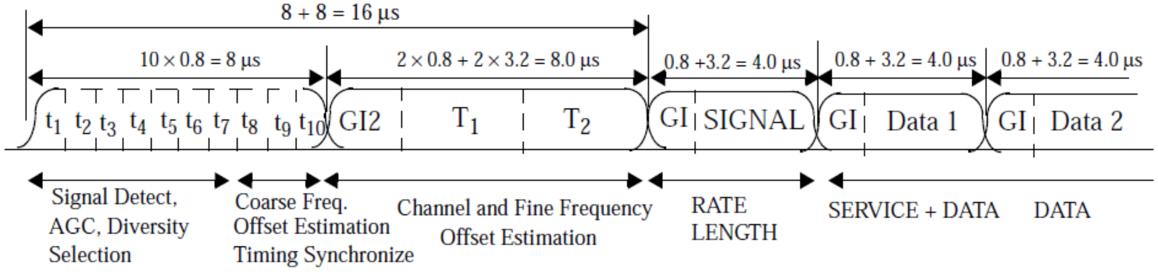
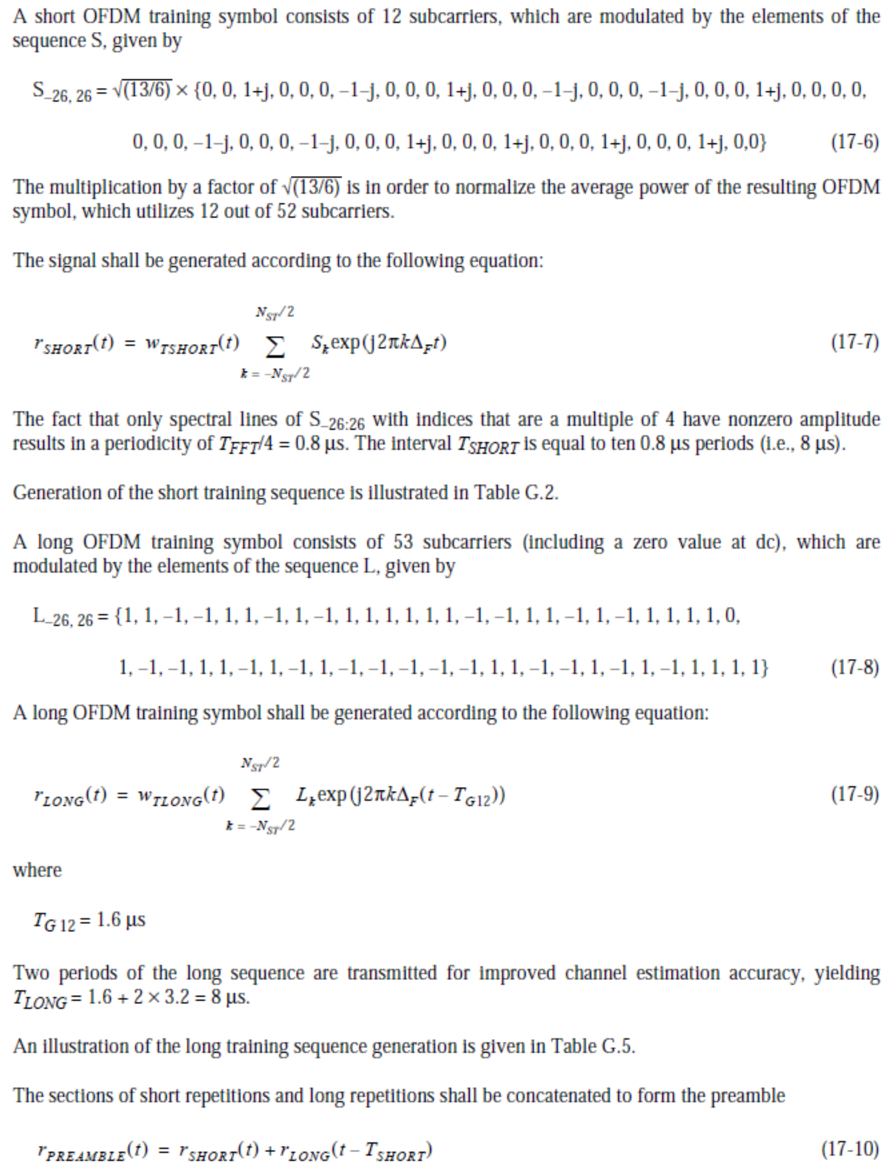


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

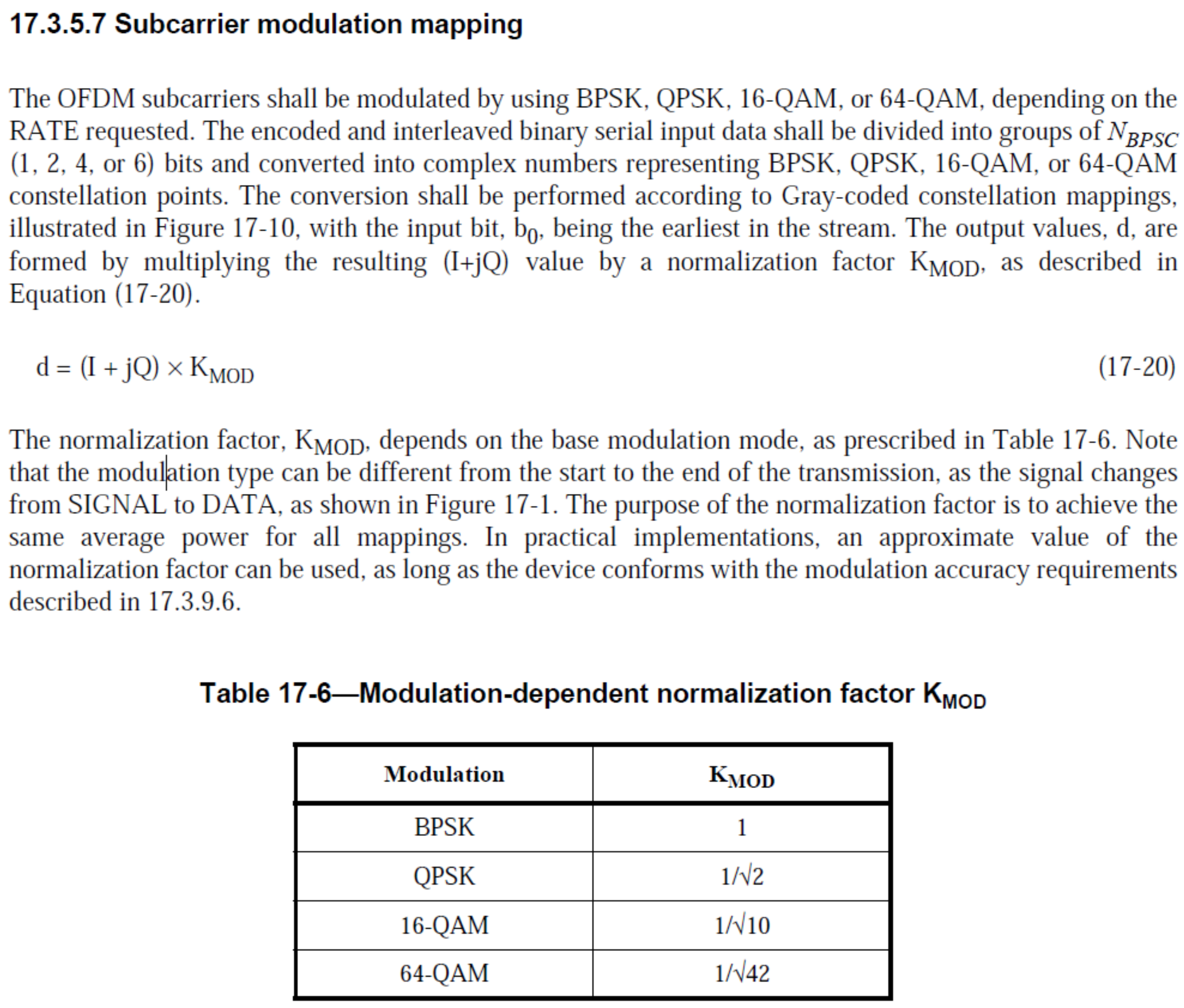
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$P_{-26,26} = \{0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

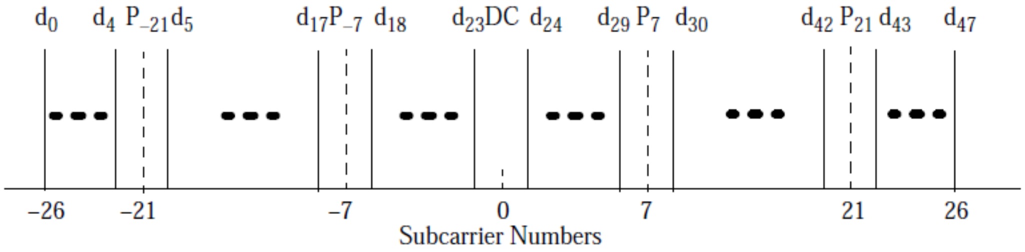


Figure 17-11—Subcarrier frequency allocation

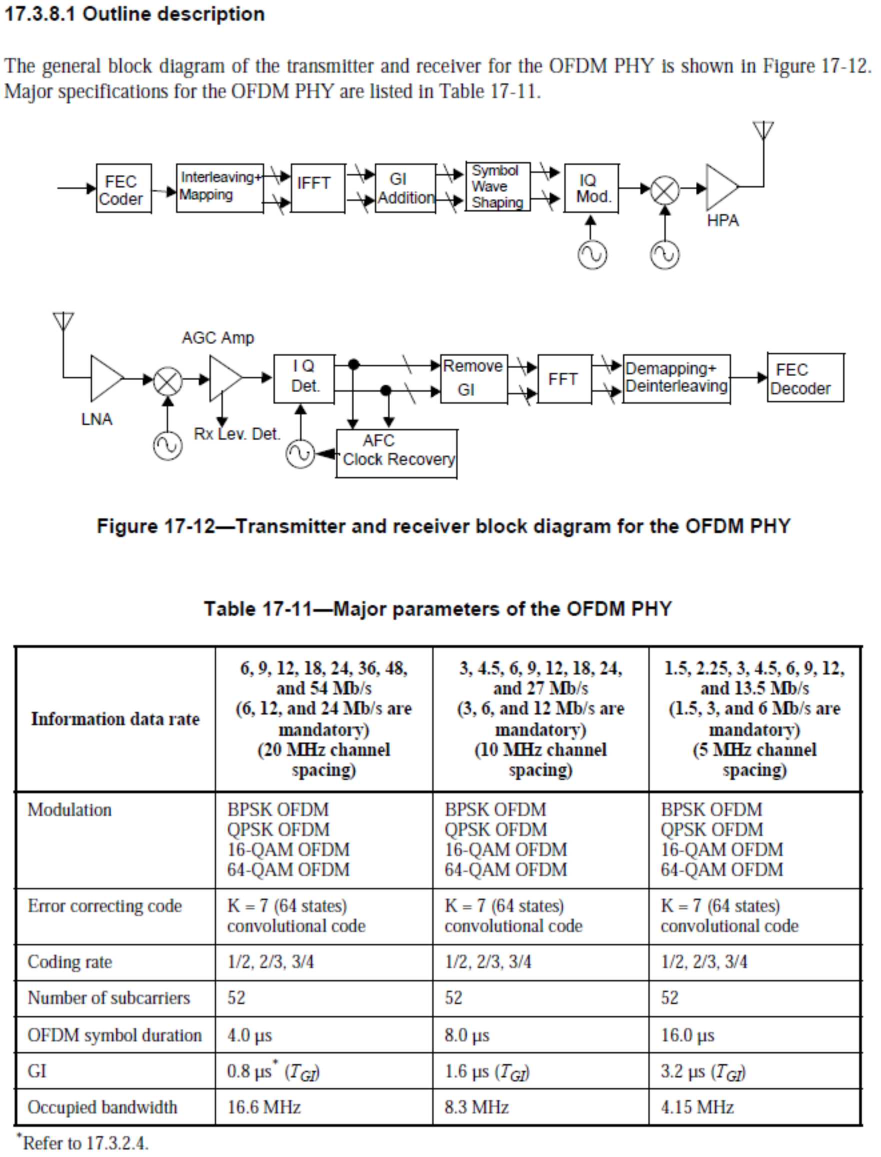
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

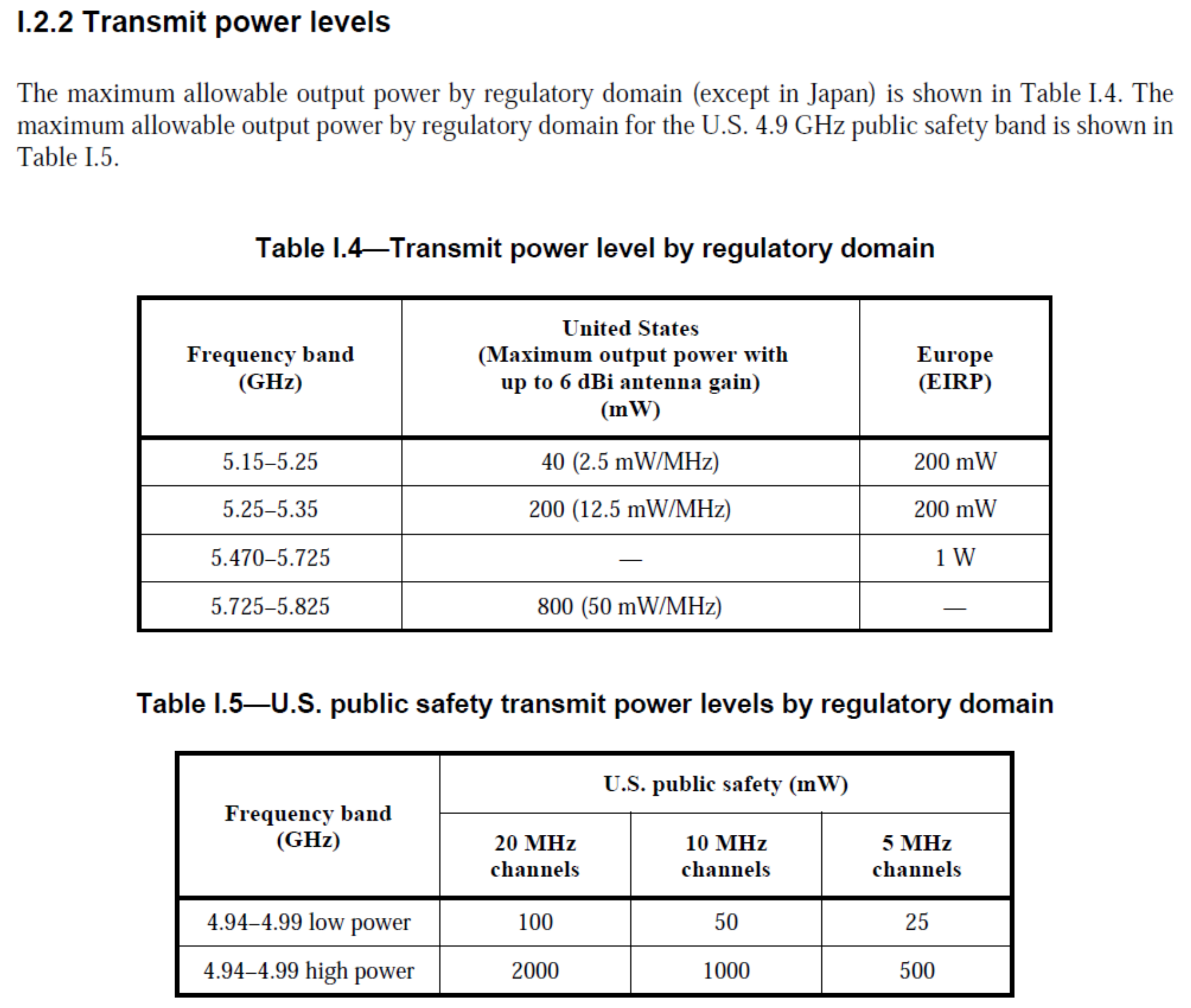
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

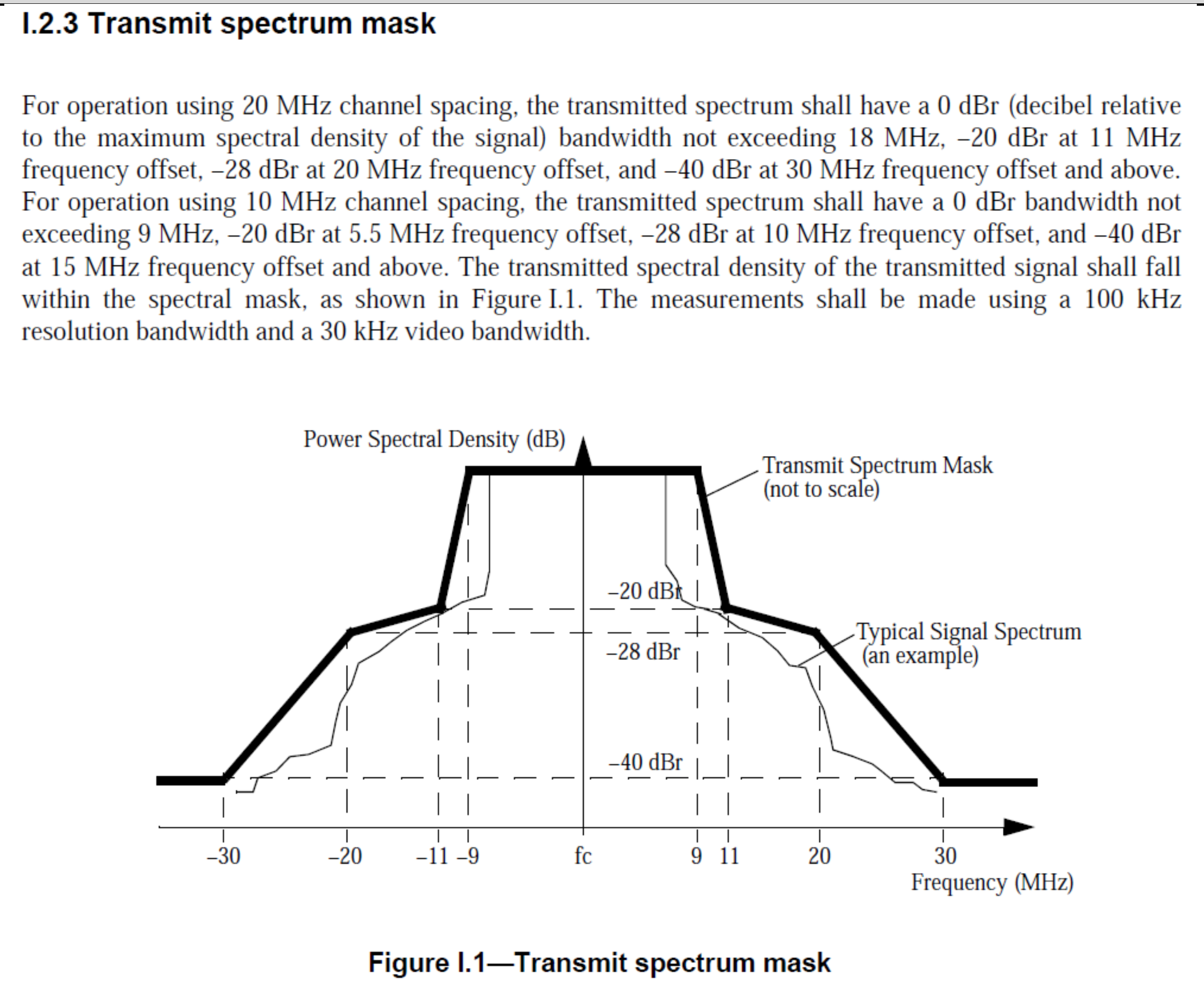
Table I.4—Transmit power level by regulatory domain

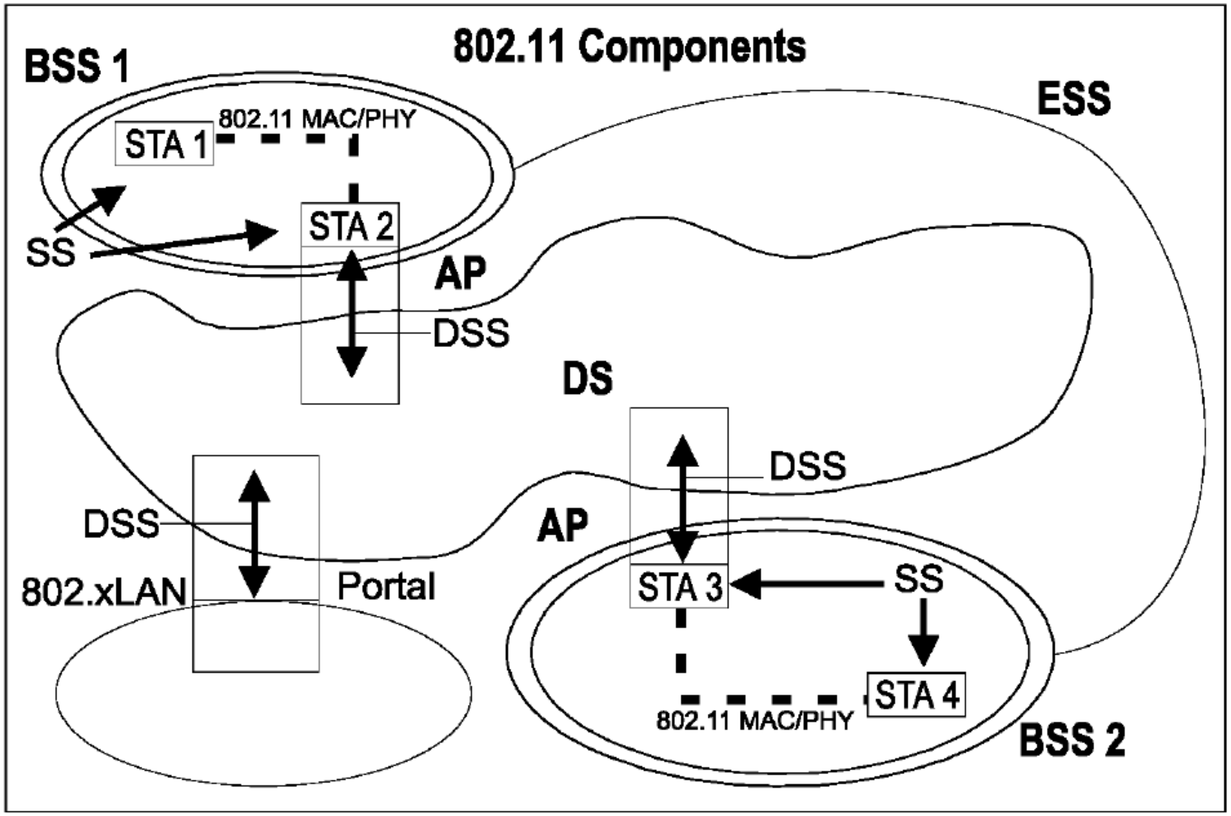
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

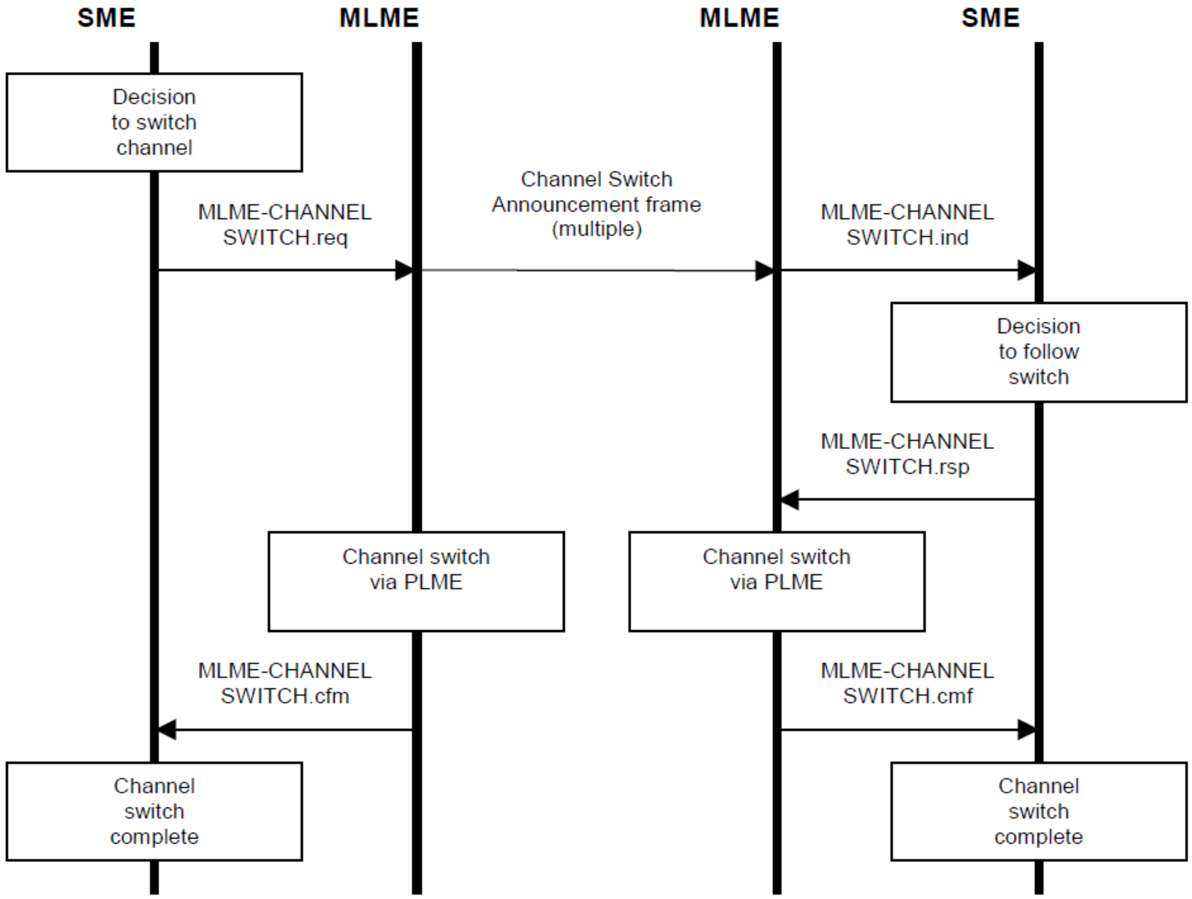
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **I.2.3 Transmit spectrum mask** For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[14.5] down-converting the amplified received up-converted signal using a first down-converter and a signal corresponding to the first RF center frequency to produce a fourth analog signal corresponding to the first analog signal; and	802.11-2007 discloses "down-converting the amplified received up-converted signal using a first down-converter and a signal corresponding to the first RF center frequency to produce a fourth analog signal corresponding to the first analog signal." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

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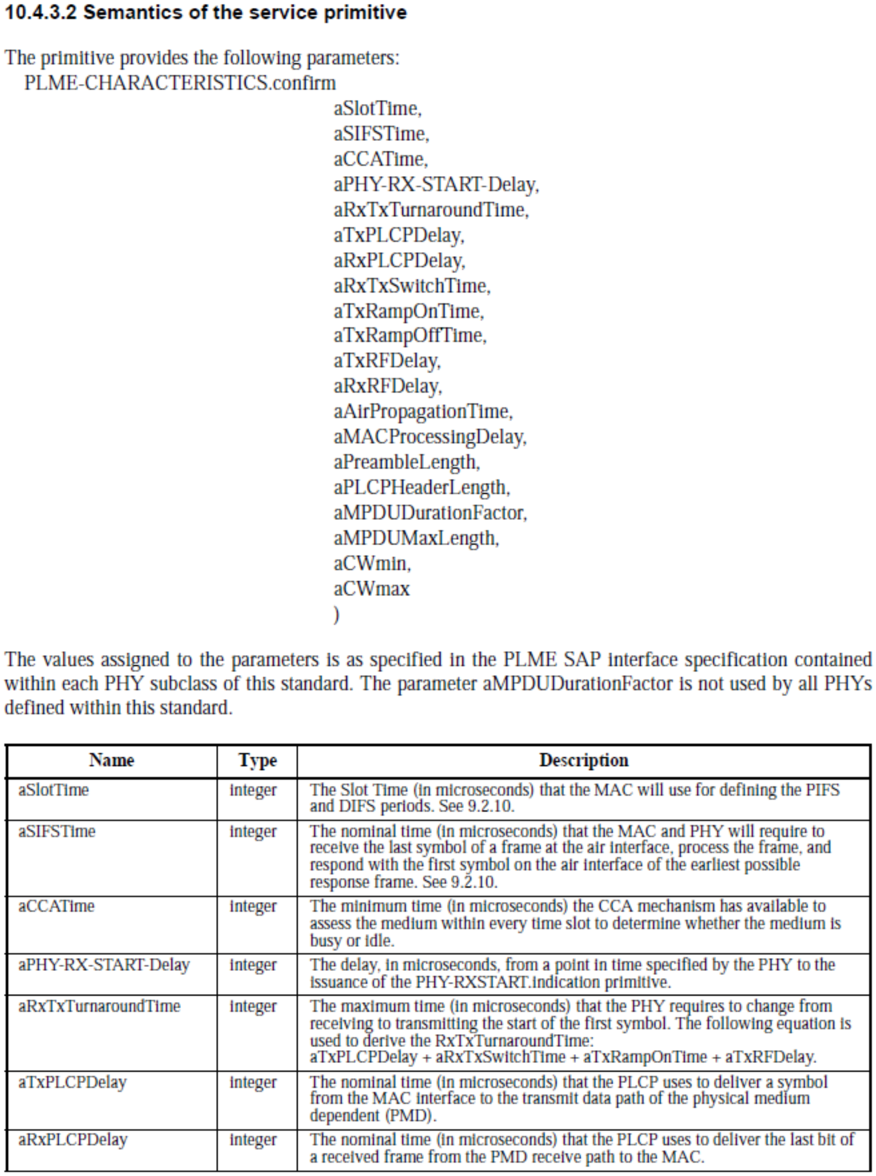
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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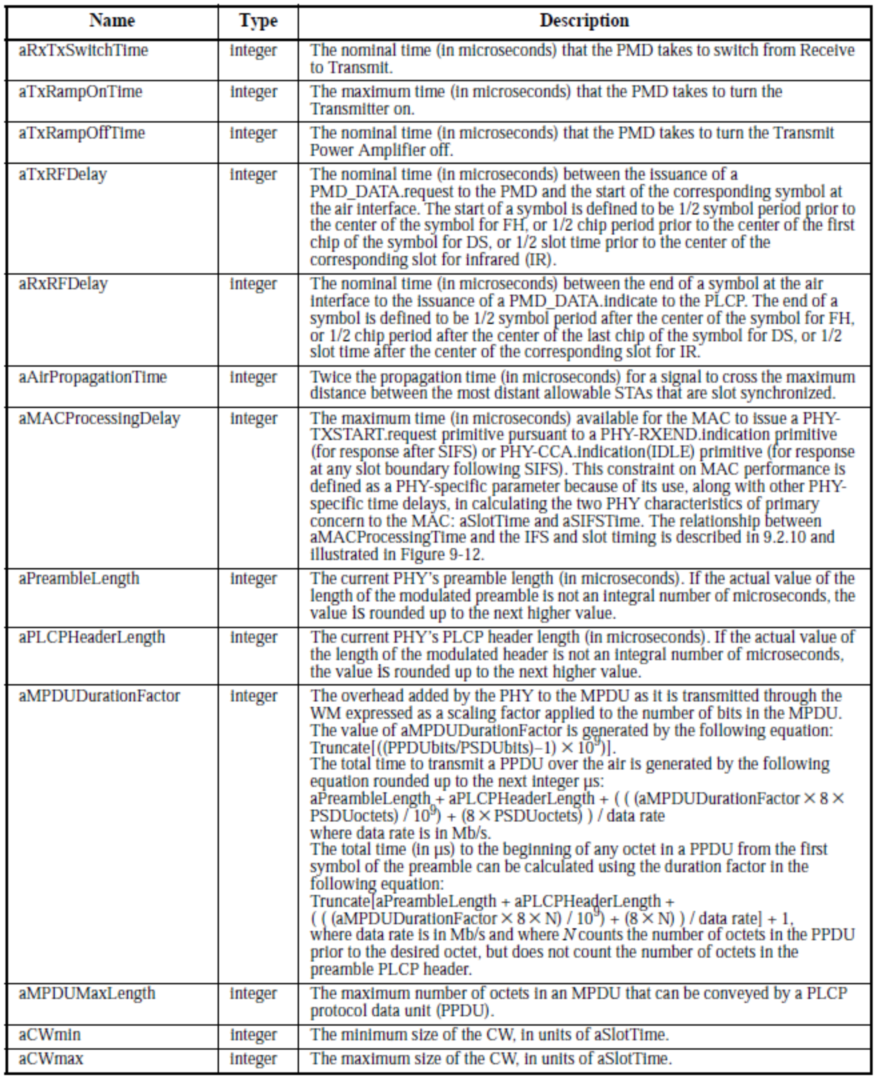

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\mathrm{Truncate}[((\mathrm{PPDUbits}/\mathrm{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times \mathrm{PSDUoctets}) / 10^9) + (8 \times \mathrm{PSDUoctets})) / \mathrm{data\ rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\mathrm{Truncate}[\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \mathrm{data\ rate}] + 1$, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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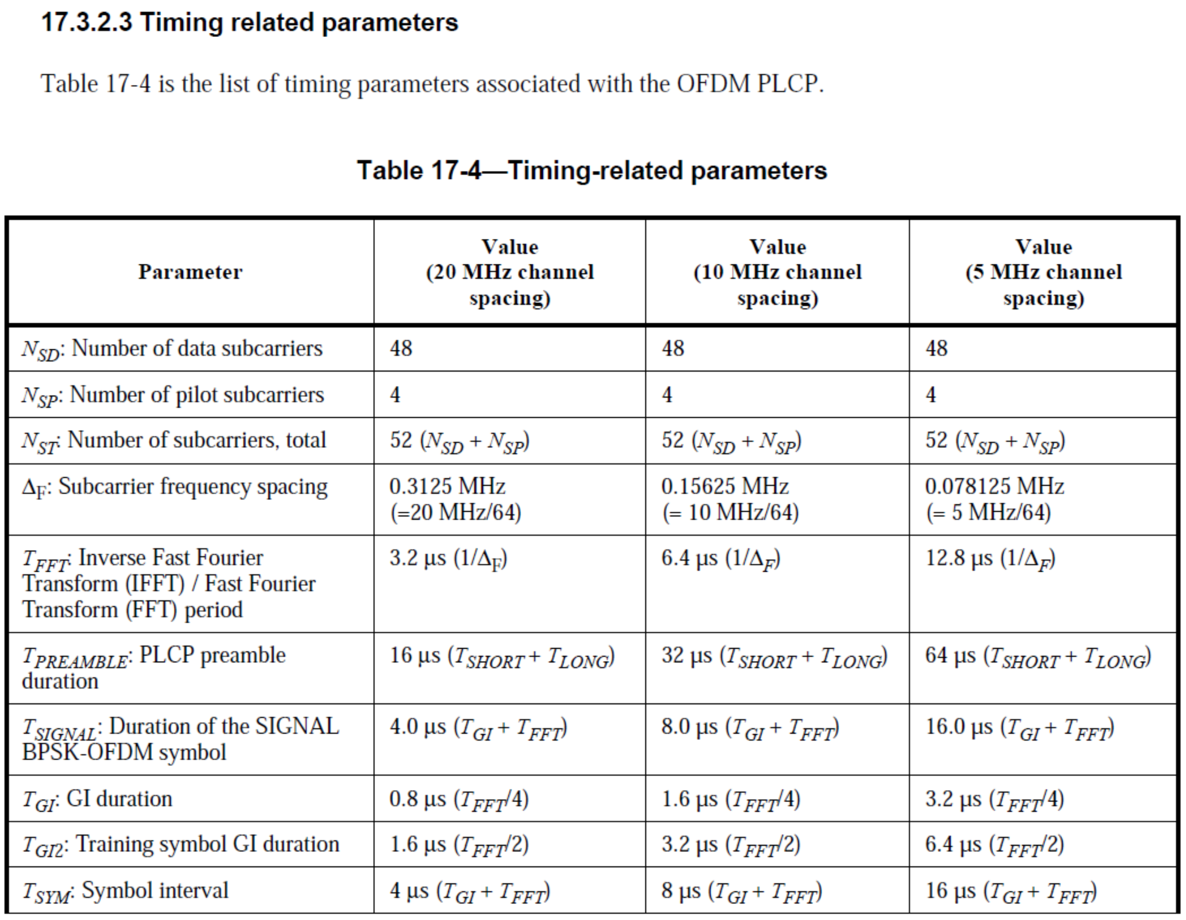
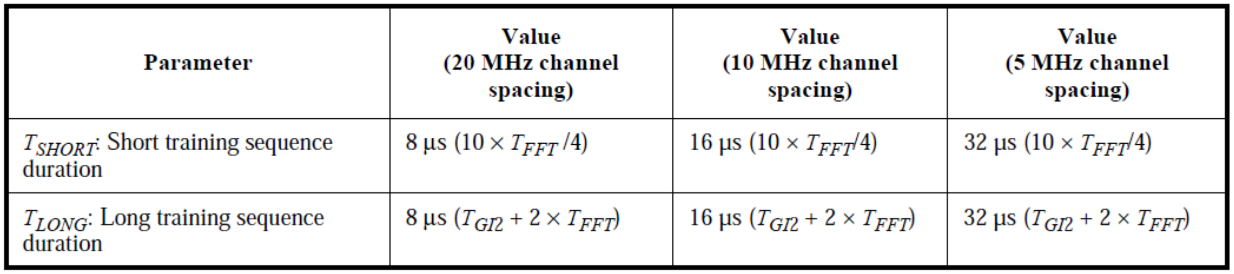
	

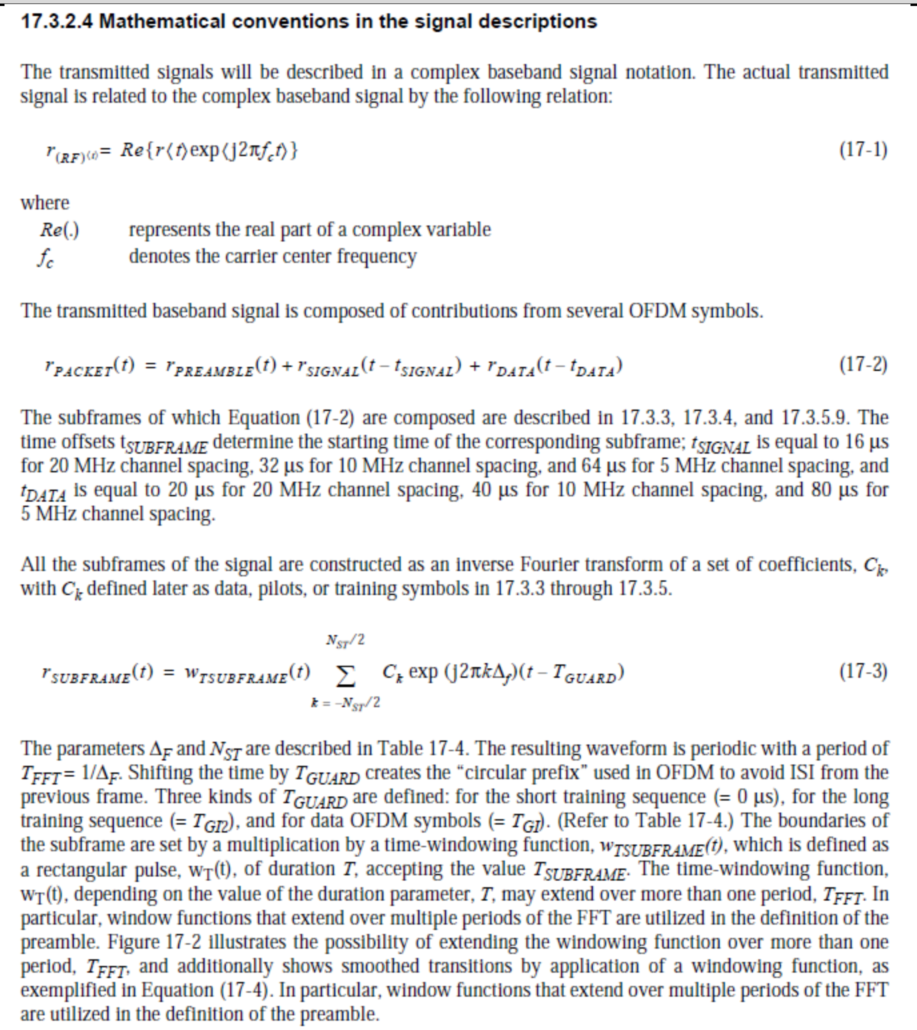
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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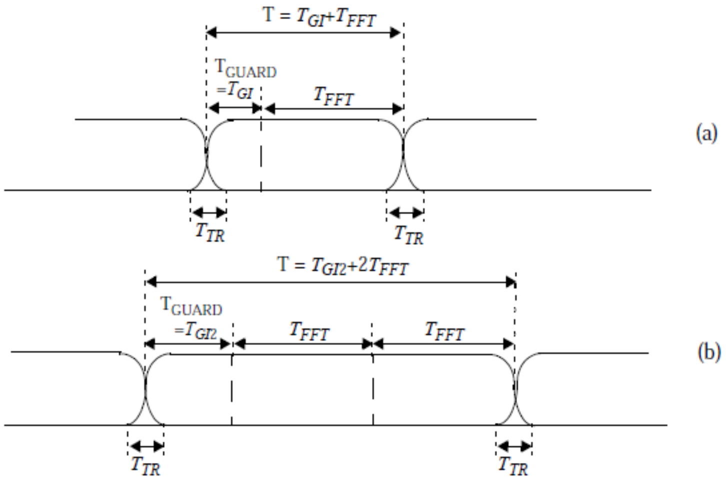
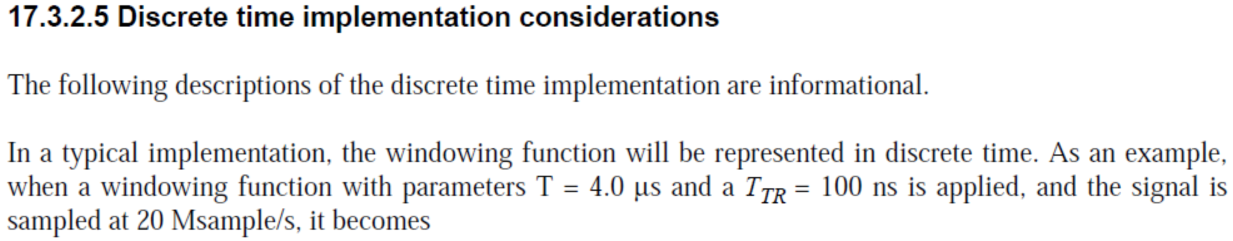
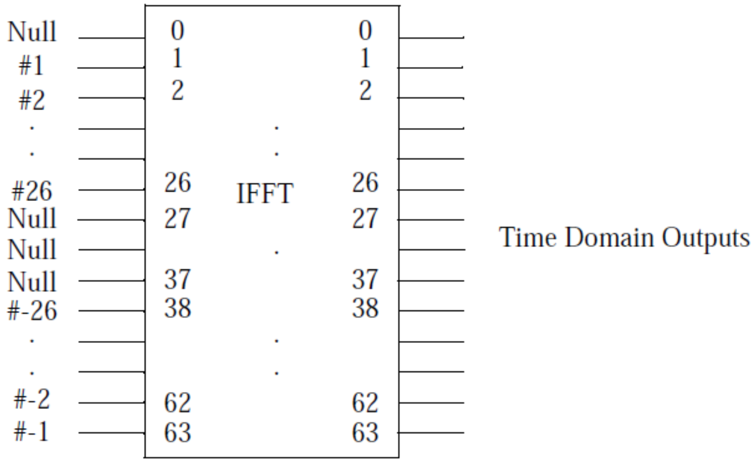
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

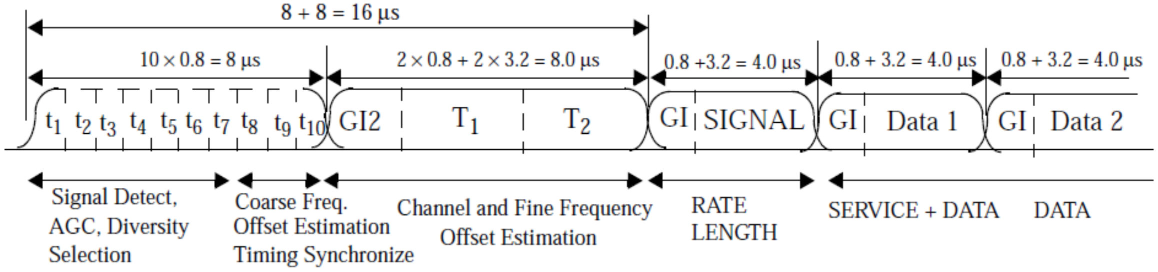


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

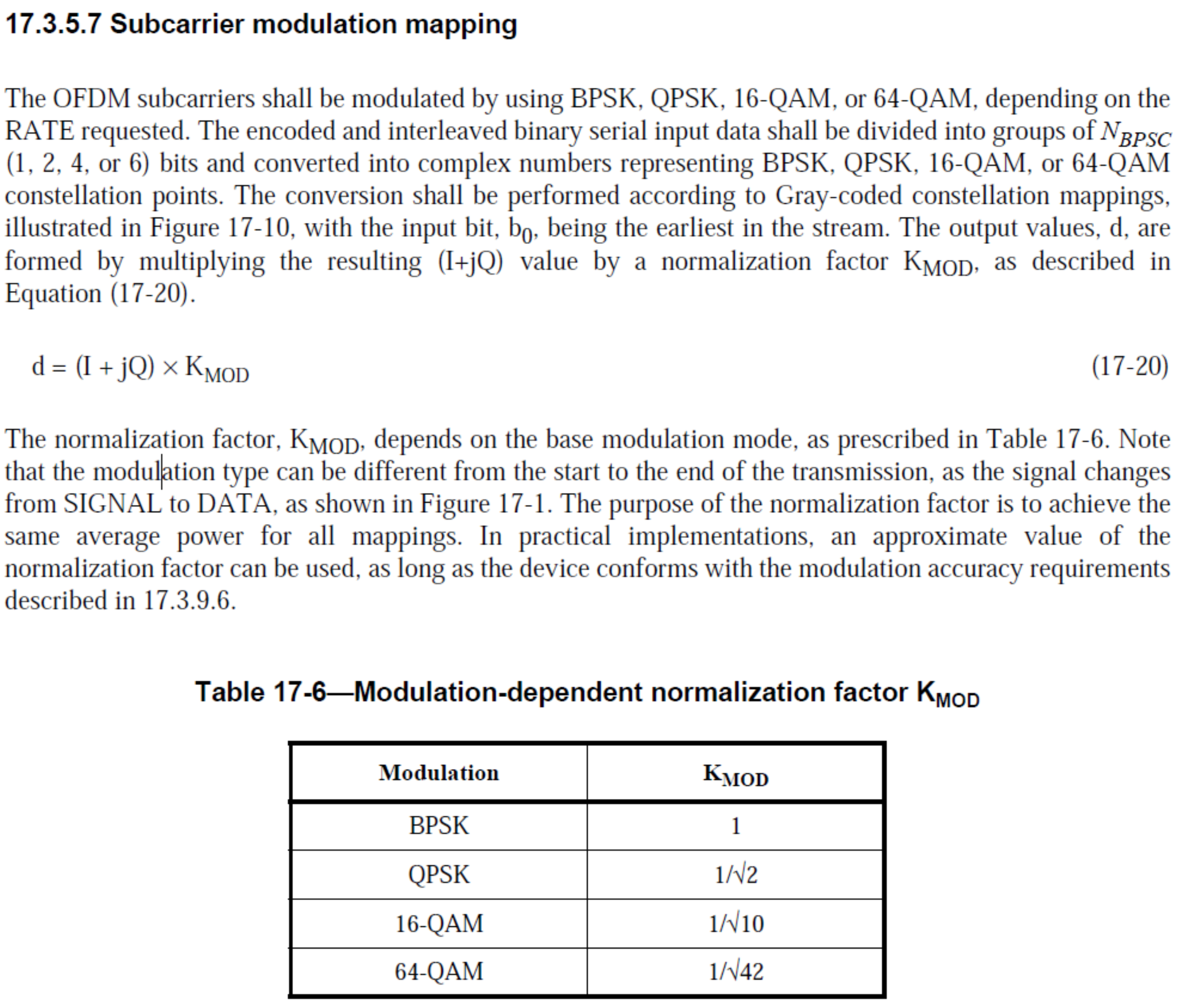
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \dots N_{SD}-1,\ n = 0, \dots N_{SYM}-1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

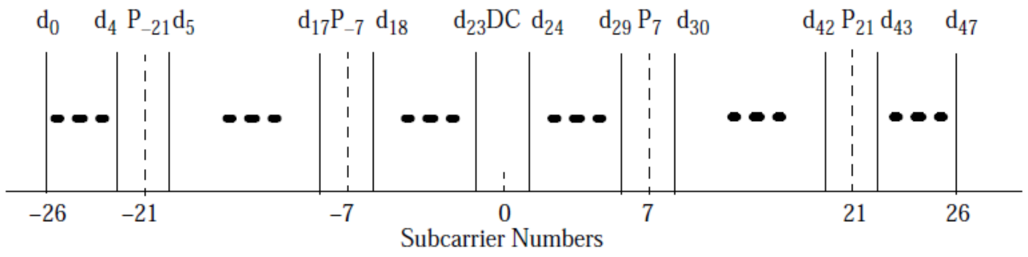


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

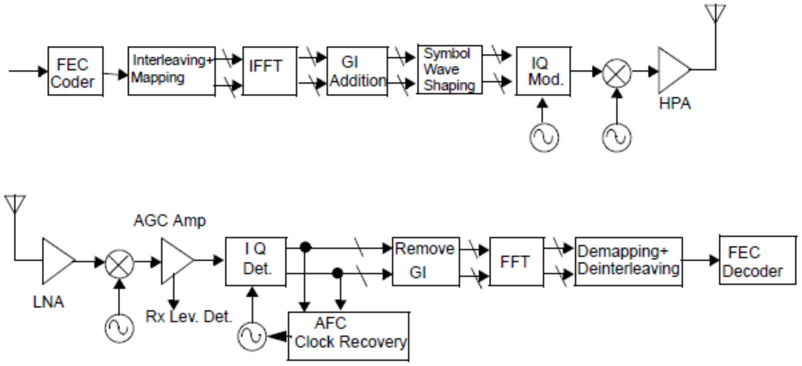


Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

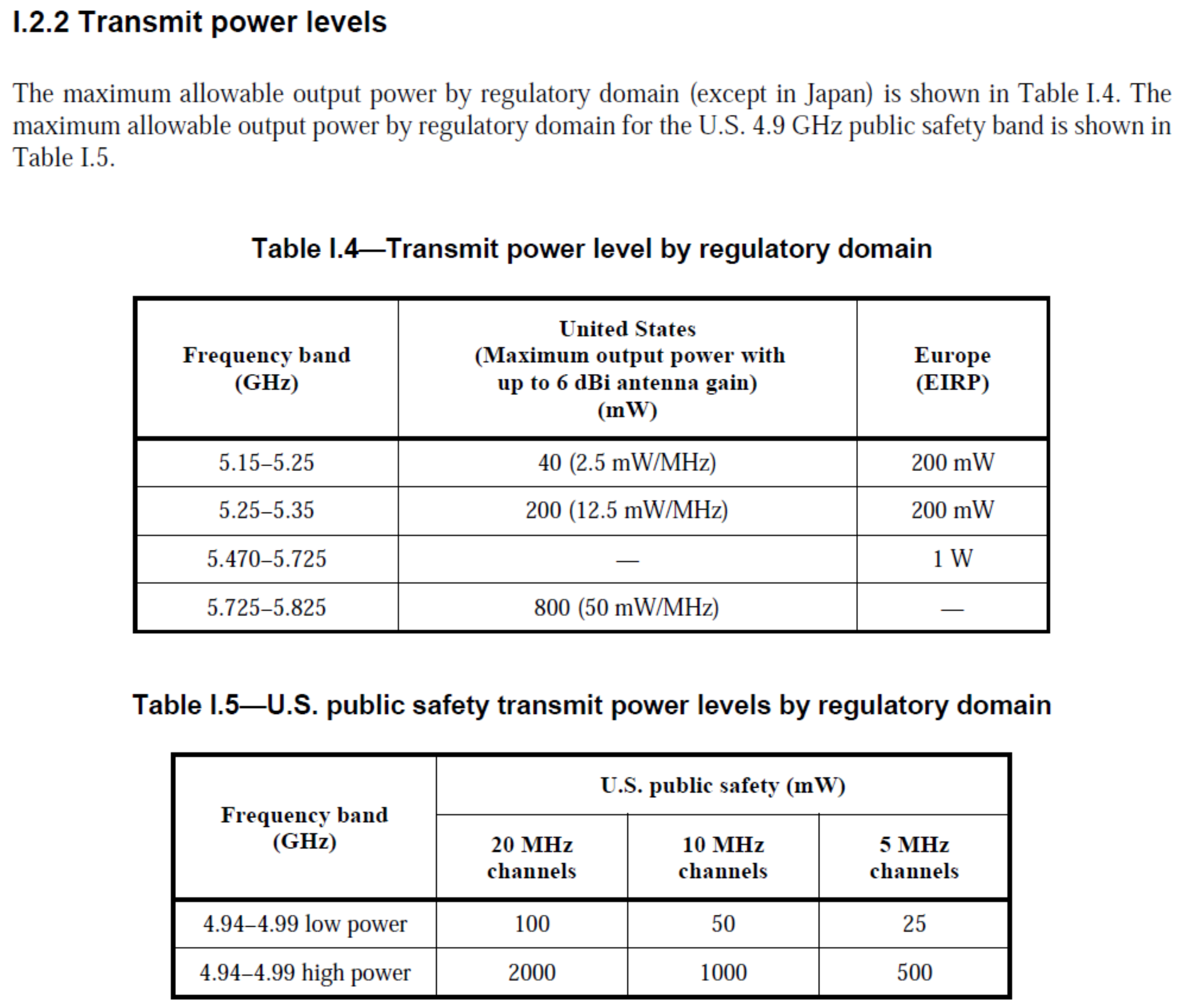
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

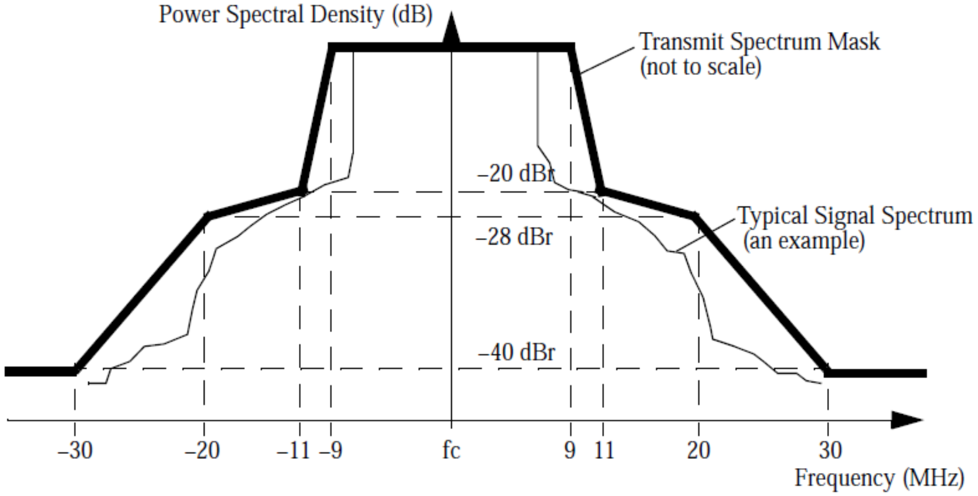
Table I.4—Transmit power level by regulatory domain

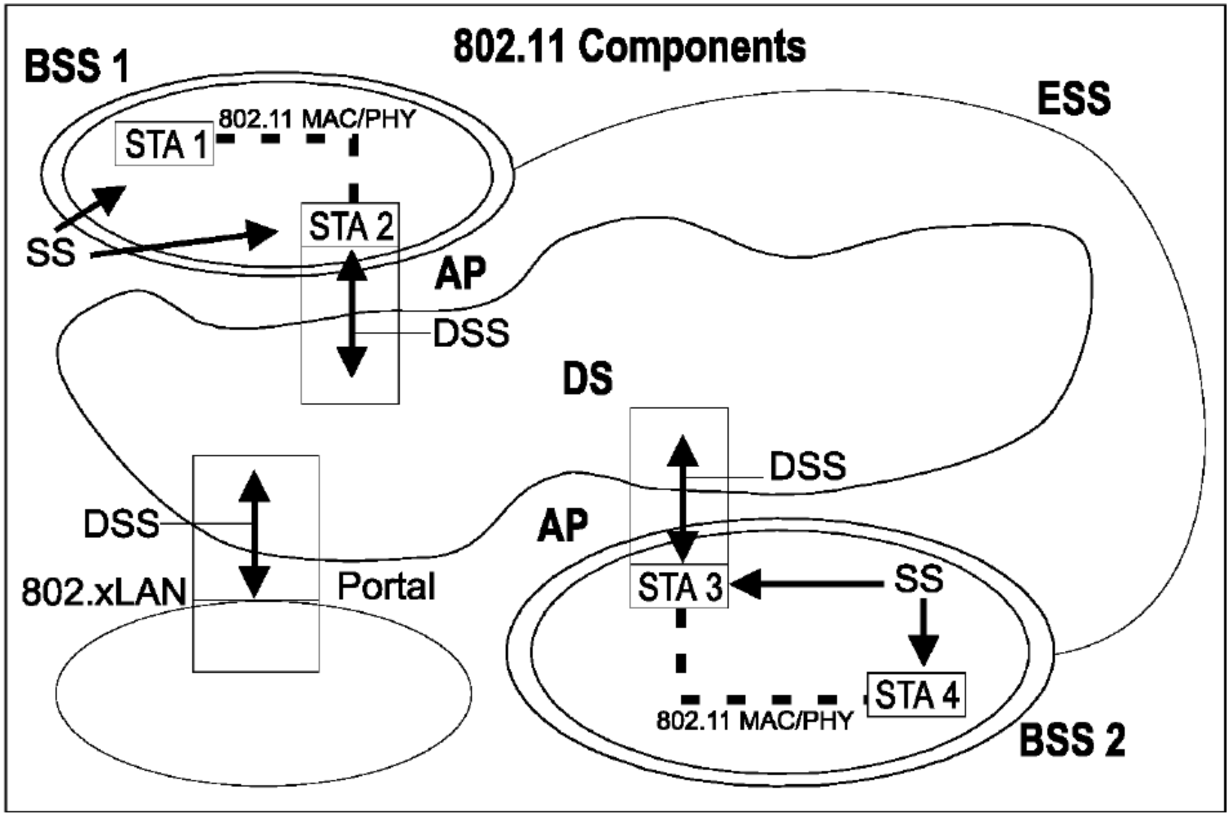
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

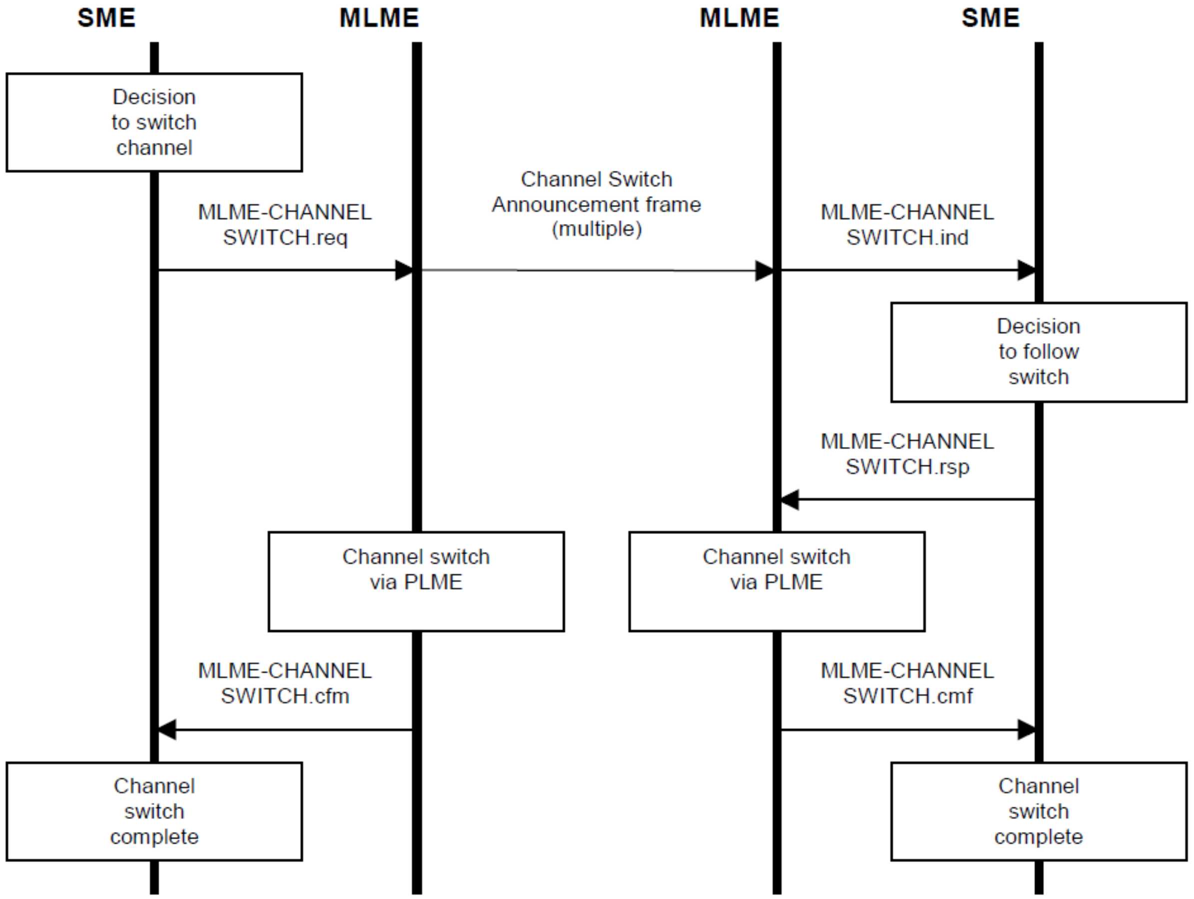
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

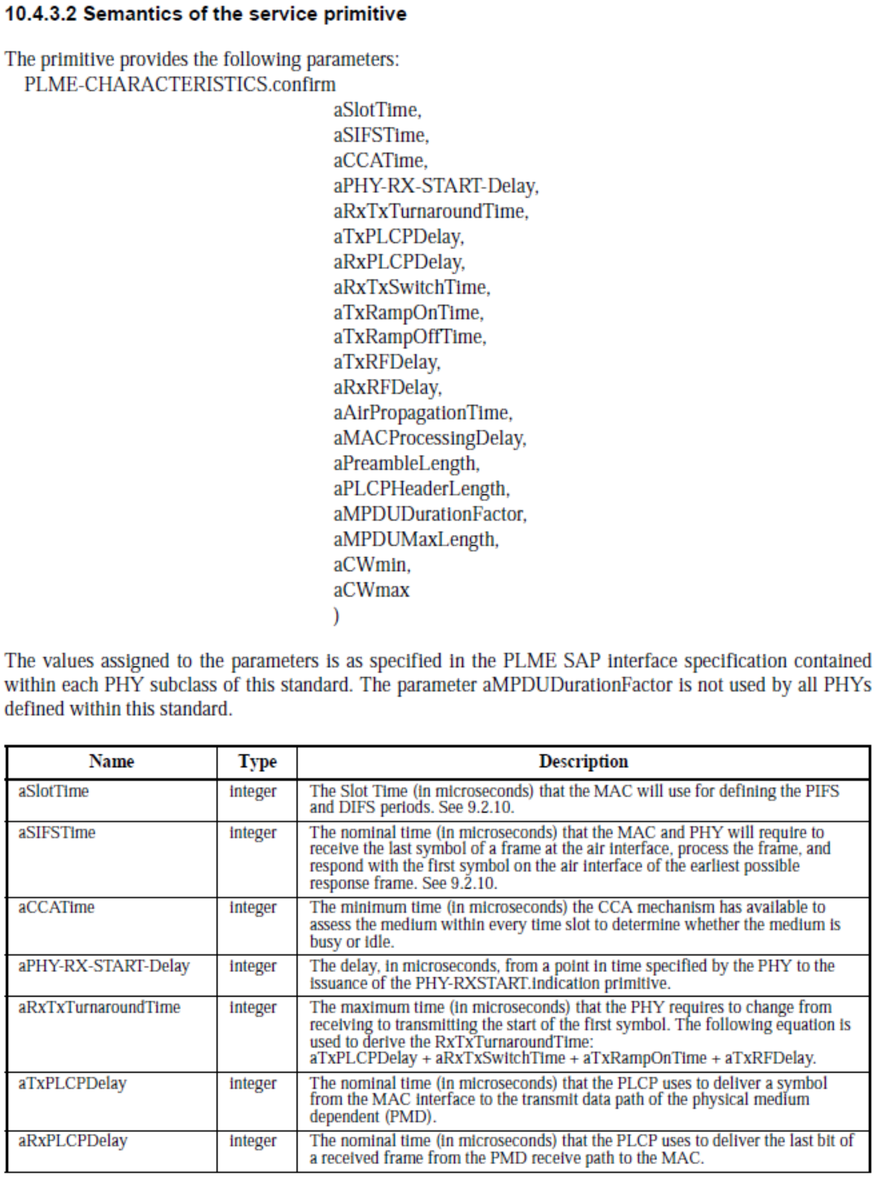
Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[14.6] down-converting the amplified received up-converted analog signal using a second down-converter and a signal corresponding to the second RF center frequency to produce a fifth analog signal corresponding to the second analog signal.	802.11-2007 discloses "down-converting the amplified received up-converted analog signal using a second down-converter and a signal corresponding to the second RF center frequency to produce a fifth analog signal corresponding to the second analog signal." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



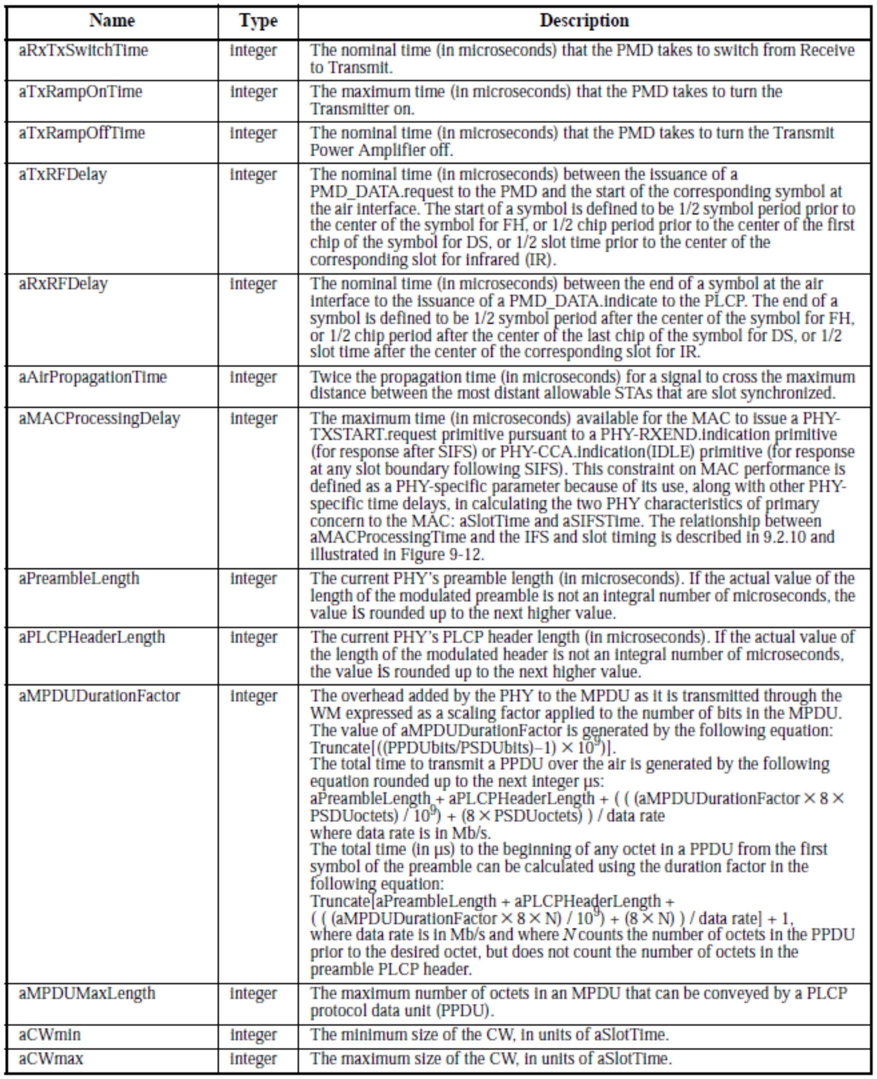
10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

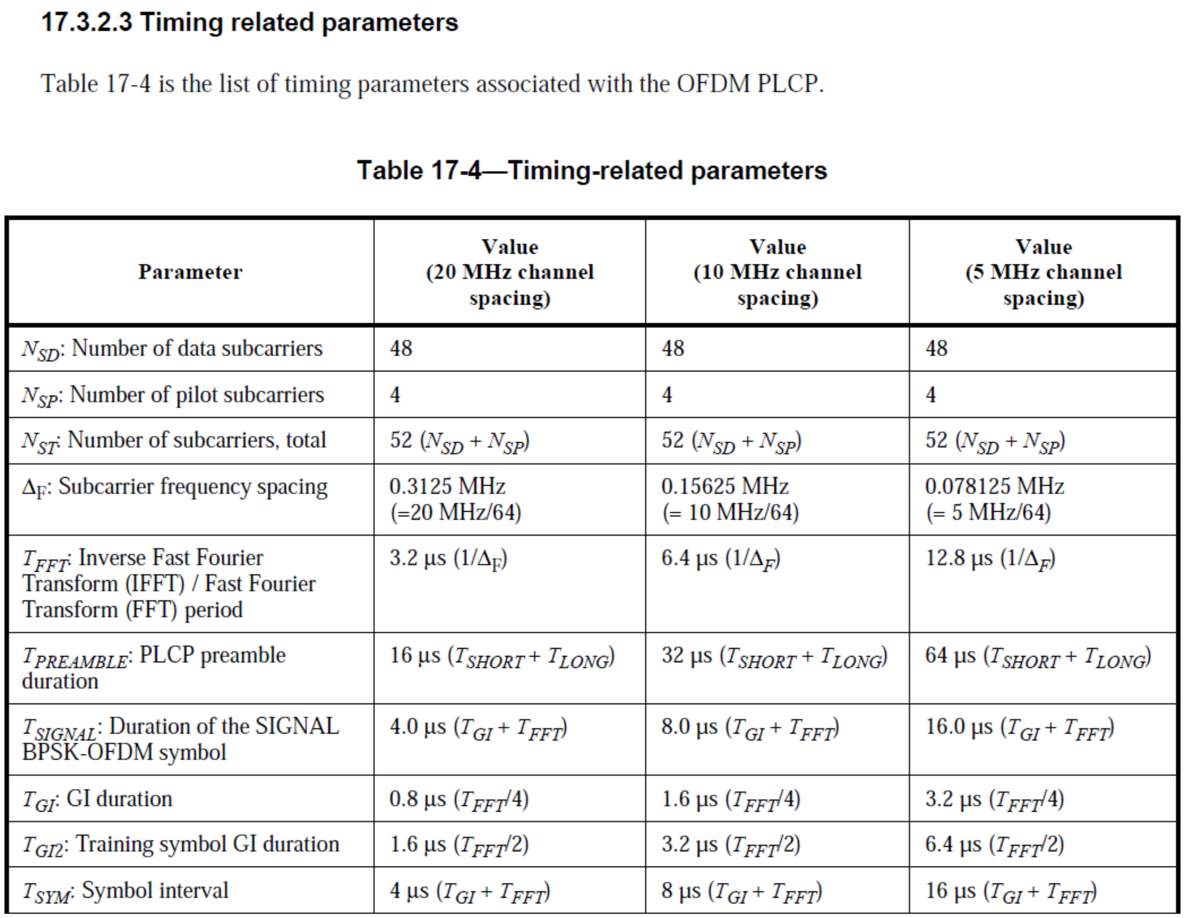
Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) $\times 10^9$)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor $\times$ 8 $\times$ PSDUoctets) / 10^9) + (8 $\times$ PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor $\times$ 8 $\times$ N) / 10^9) + (8 $\times$ N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

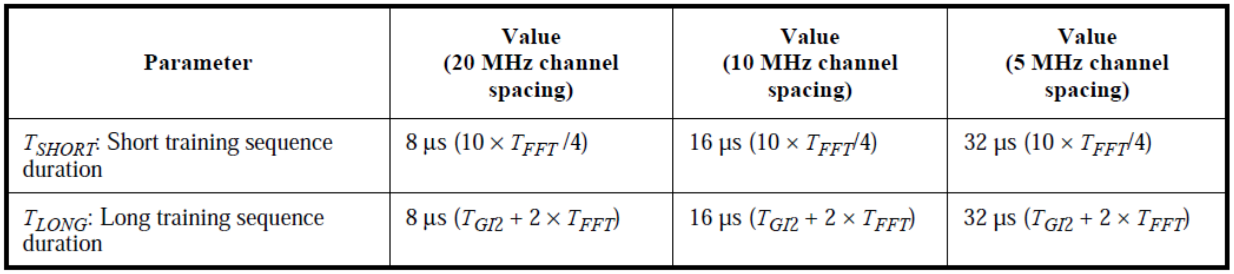
Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

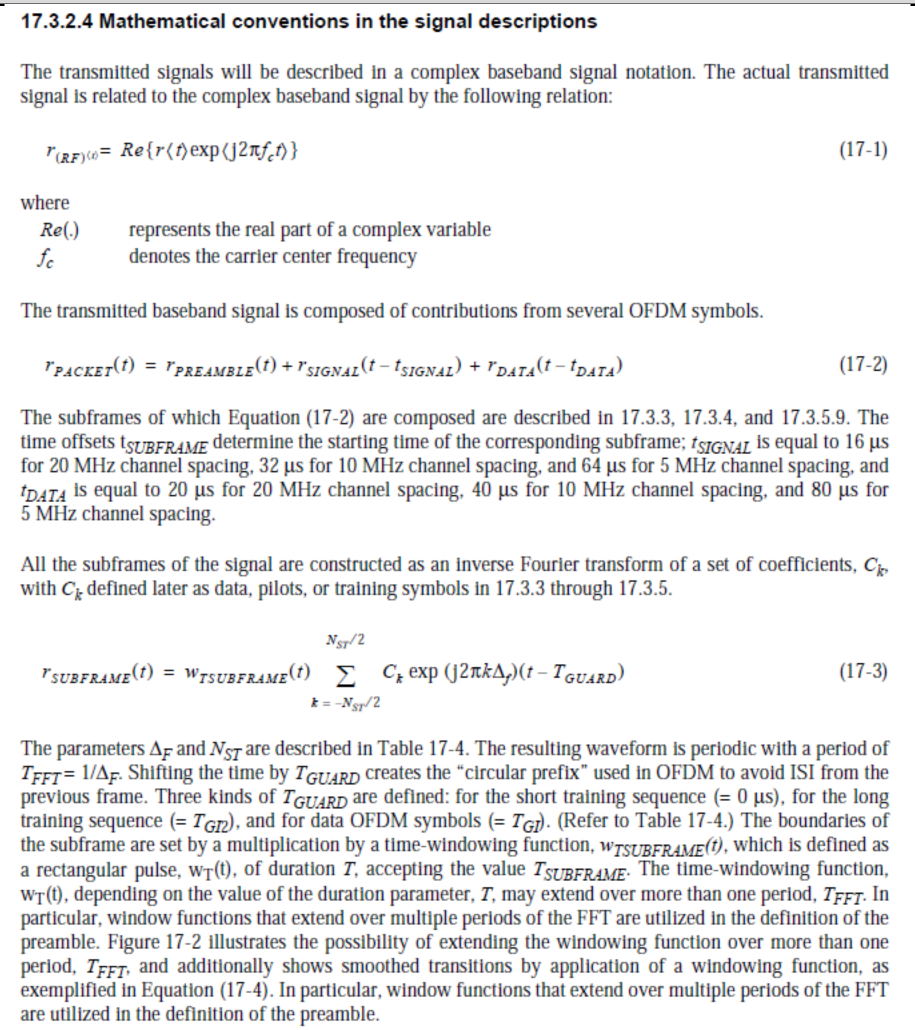
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$	represents the real part of a complex variable
f_c	denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

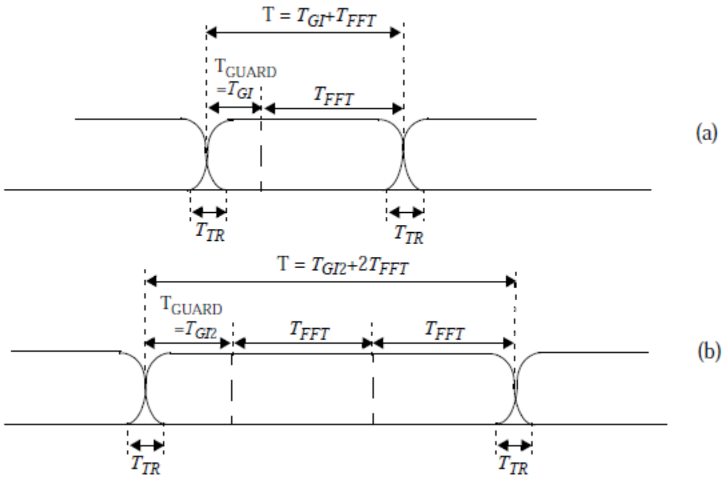
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

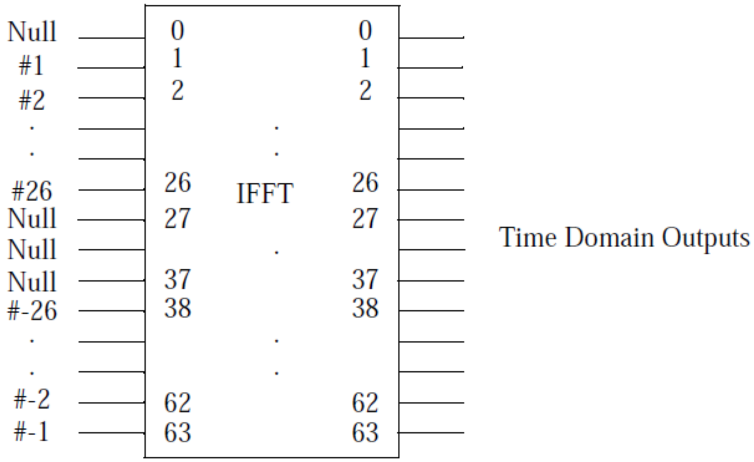
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

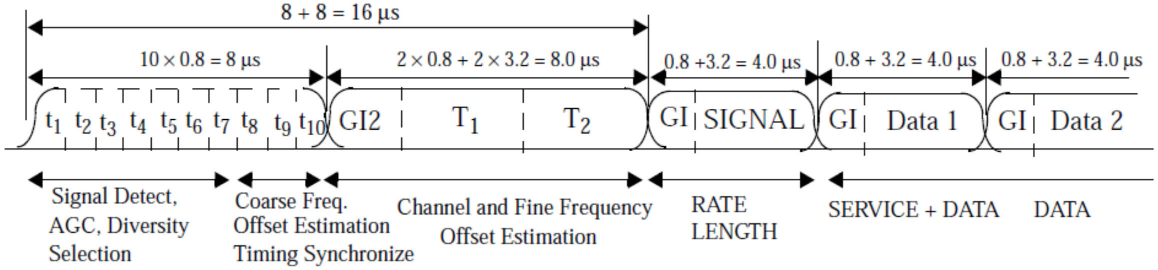
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

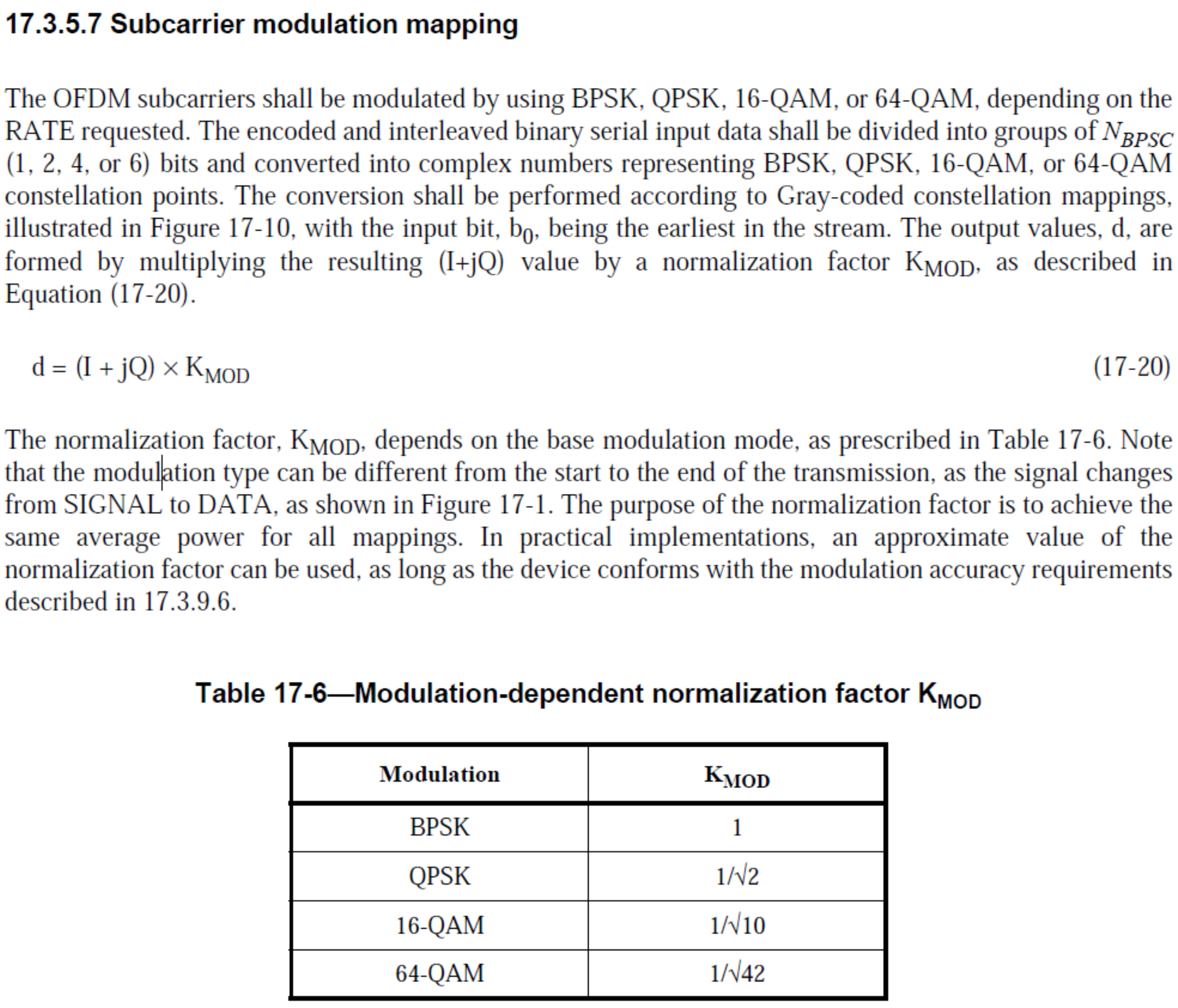
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

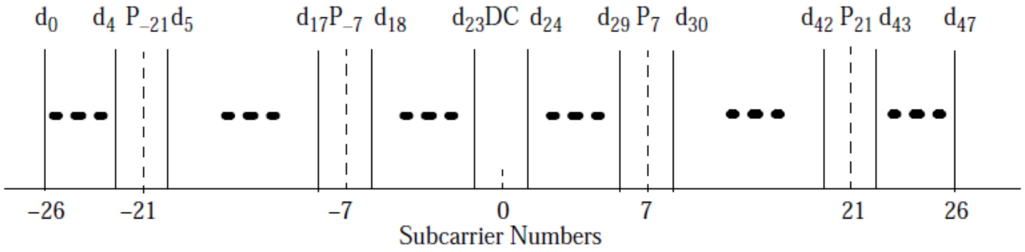


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.8.1 Outline description

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

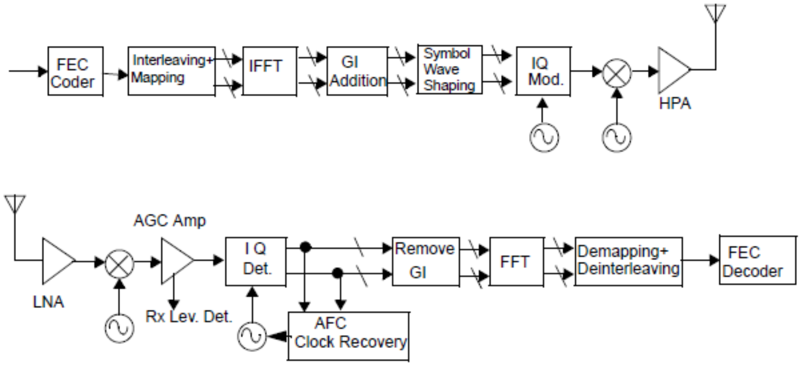


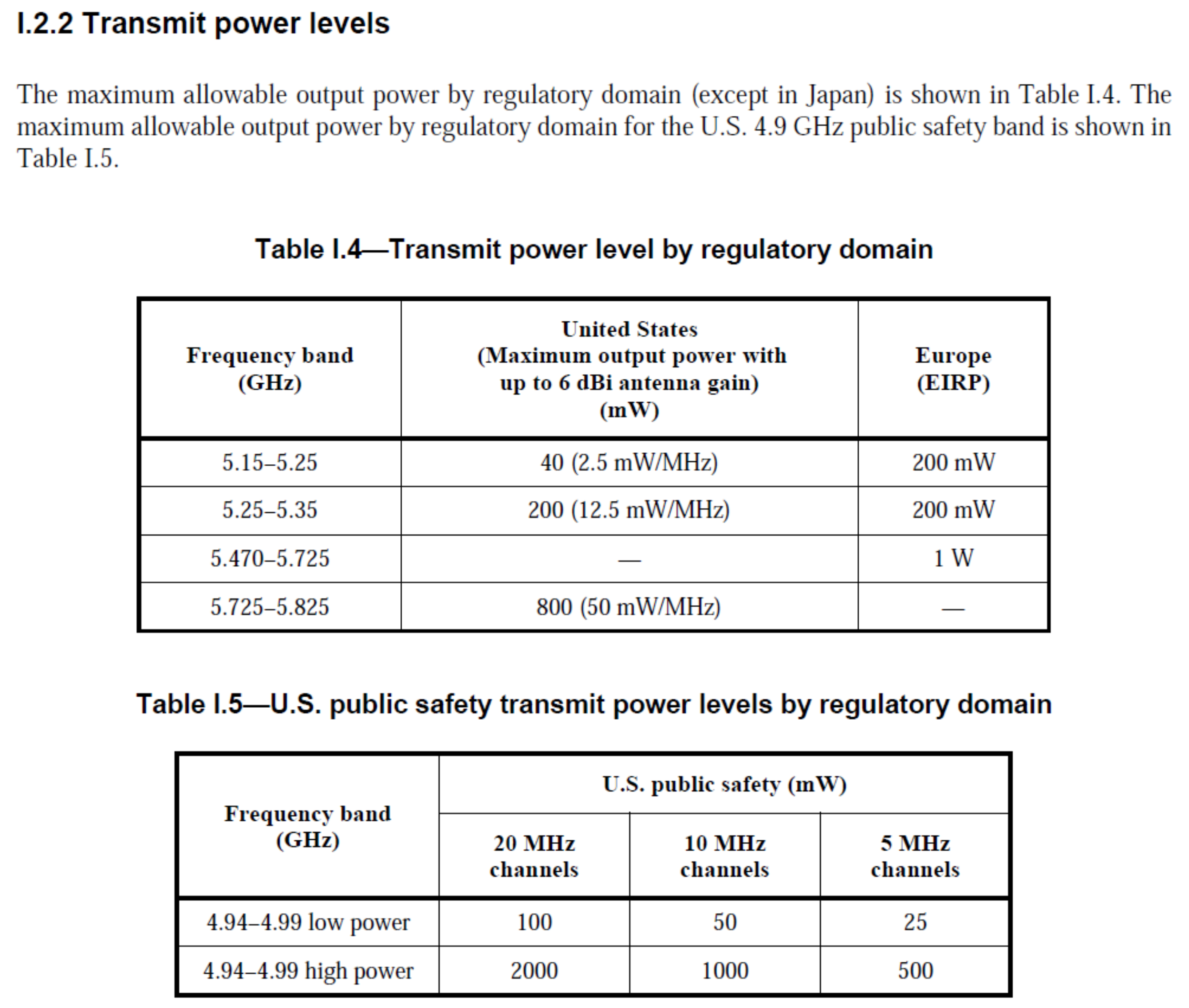
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

<table>
<tr><th>Claim 14 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


<h3>I.2.2 Transmit power levels</h3>

<p>The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.</p>

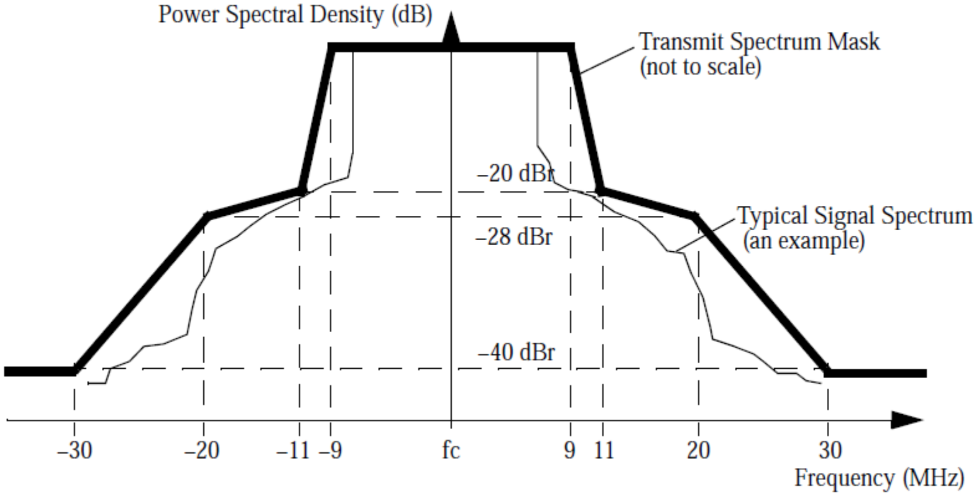
<p>Table I.4—Transmit power level by regulatory domain</p>

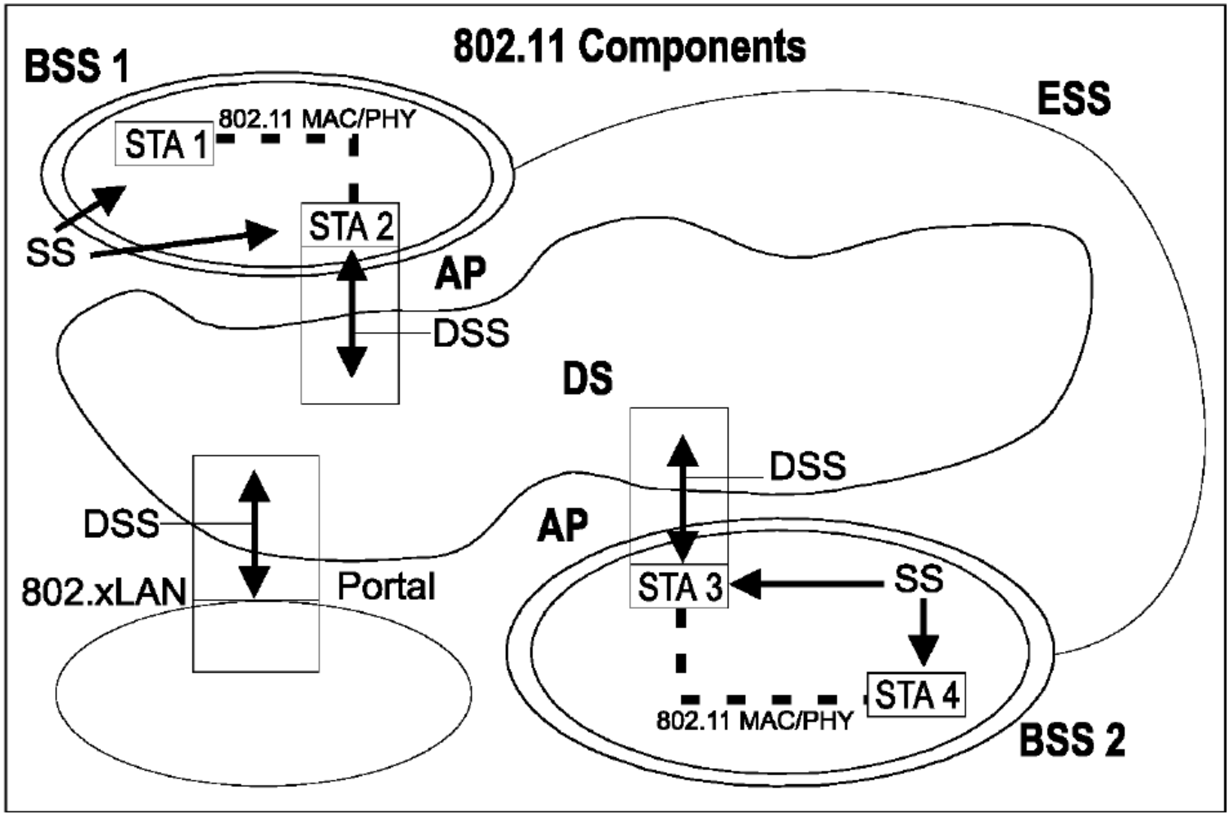
<table>
<tr><th>Frequency band (GHz)</th><th>United States (Maximum output power with up to 6 dBi antenna gain) (mW)</th><th>Europe (EIRP)</th></tr>
<tr><td>5.15–5.25</td><td>40 (2.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.25–5.35</td><td>200 (12.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.470–5.725</td><td>—</td><td>1 W</td></tr>
<tr><td>5.725–5.825</td><td>800 (50 mW/MHz)</td><td>—</td></tr>
</table>

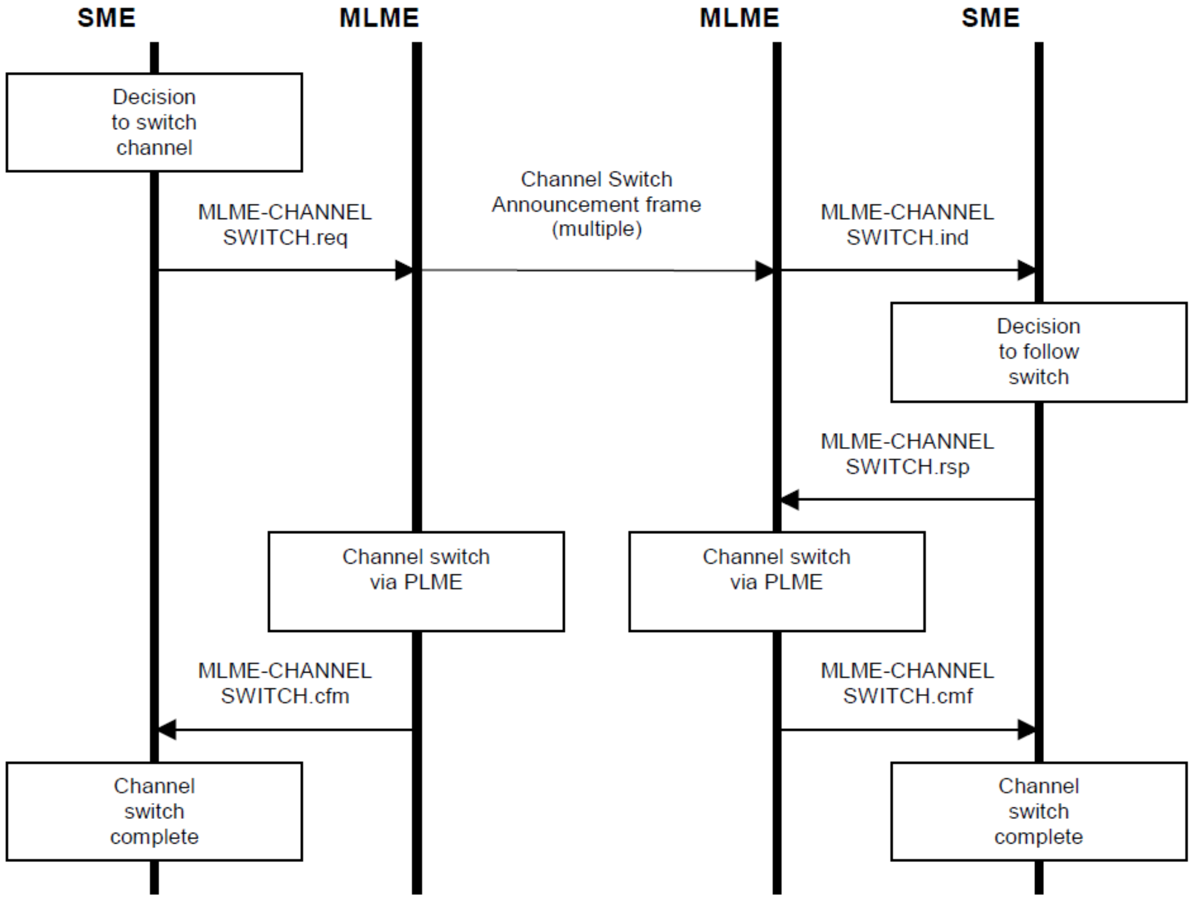
<p>Table I.5—U.S. public safety transmit power levels by regulatory domain</p>

<table>
<tr><th rowspan="2">Frequency band (GHz)</th><th colspan="3">U.S. public safety (mW)</th></tr>
<tr><th>20 MHz channels</th><th>10 MHz channels</th><th>5 MHz channels</th></tr>
<tr><td>4.94–4.99 low power</td><td>100</td><td>50</td><td>25</td></tr>
<tr><td>4.94–4.99 high power</td><td>2000</td><td>1000</td><td>500</td></tr>
</table>

<p>See, e.g., 802.11-2007 § I.2.2</p>
</td></tr>
</table>

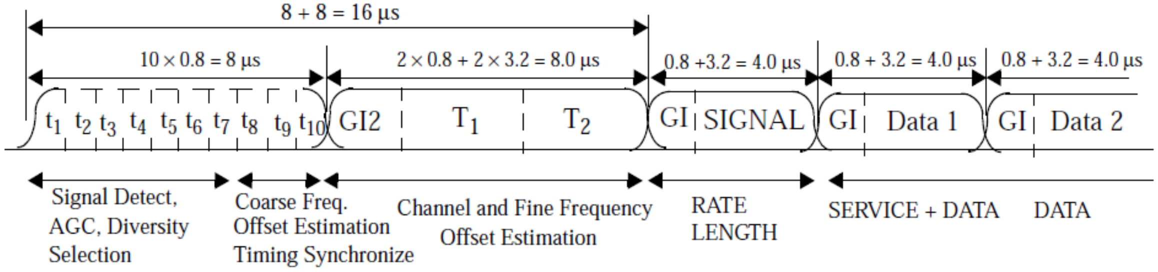
Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

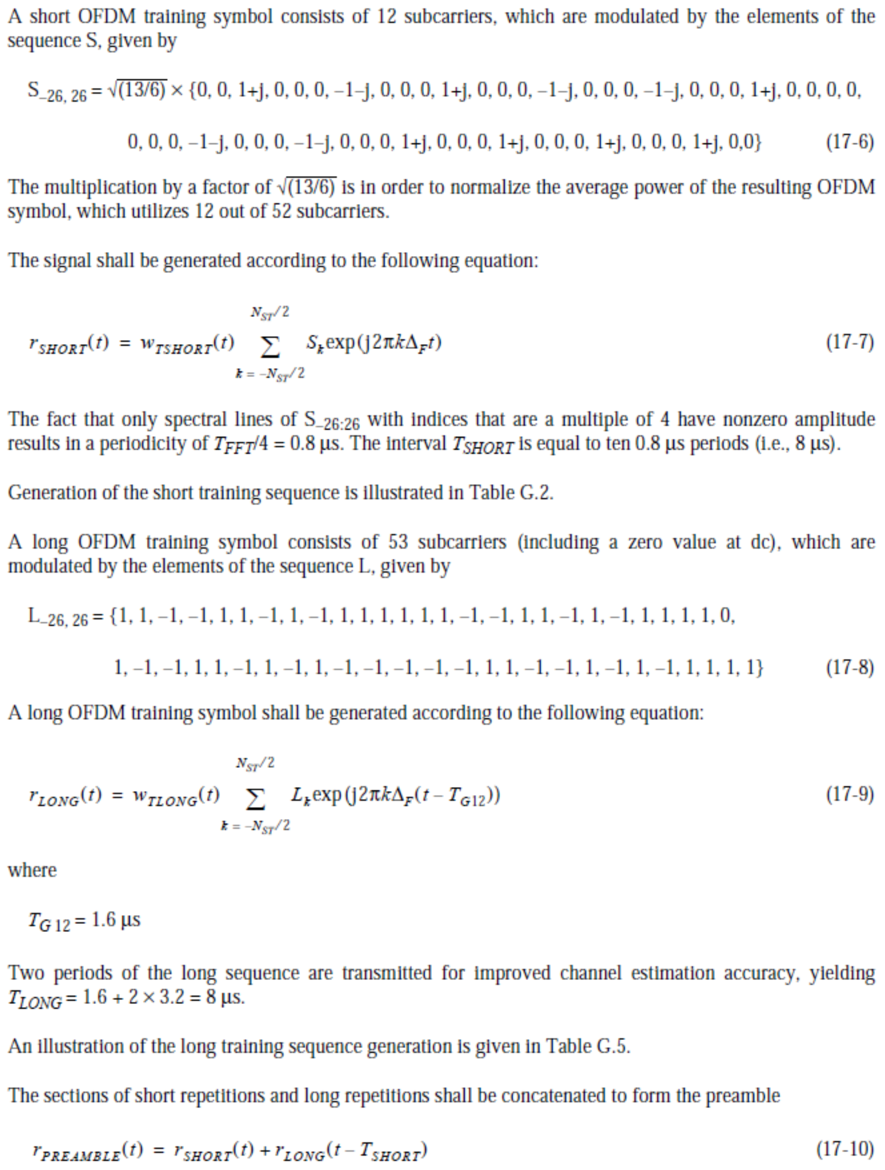
Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 14 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 14 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
[17.1] A wireless communication system comprising:	To the extent the preamble is limiting, 802.11-2007 discloses “A wireless communication system comprising.” See, e.g.:

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

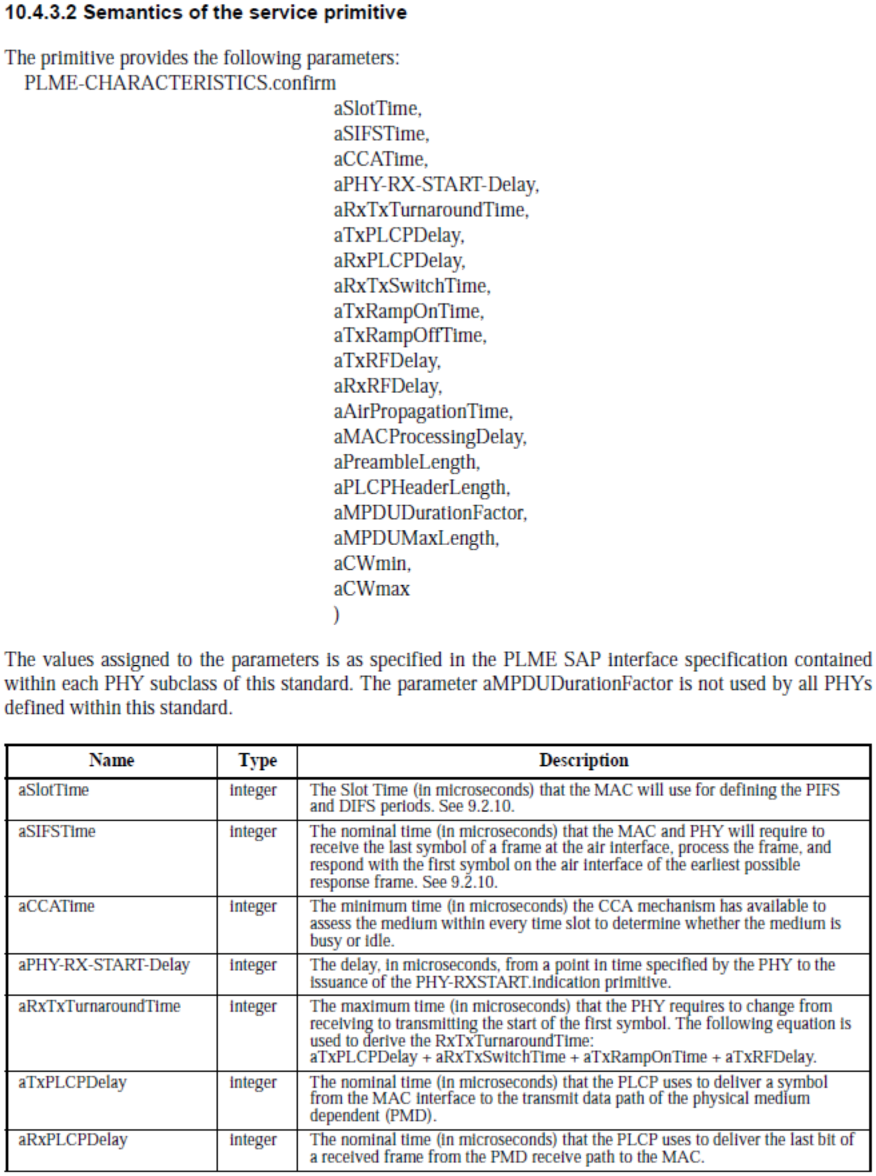
See, e.g., 802.11-2007 § 17.3.3

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.2] a baseband digital system for providing a first digital signal comprising a first data to be transmitted and a second digital signal comprising a second data to be transmitted;	802.11-2007 discloses “a baseband digital system for providing a first digital signal comprising a first data to be transmitted and a second digital signal comprising a second data to be transmitted.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts**

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

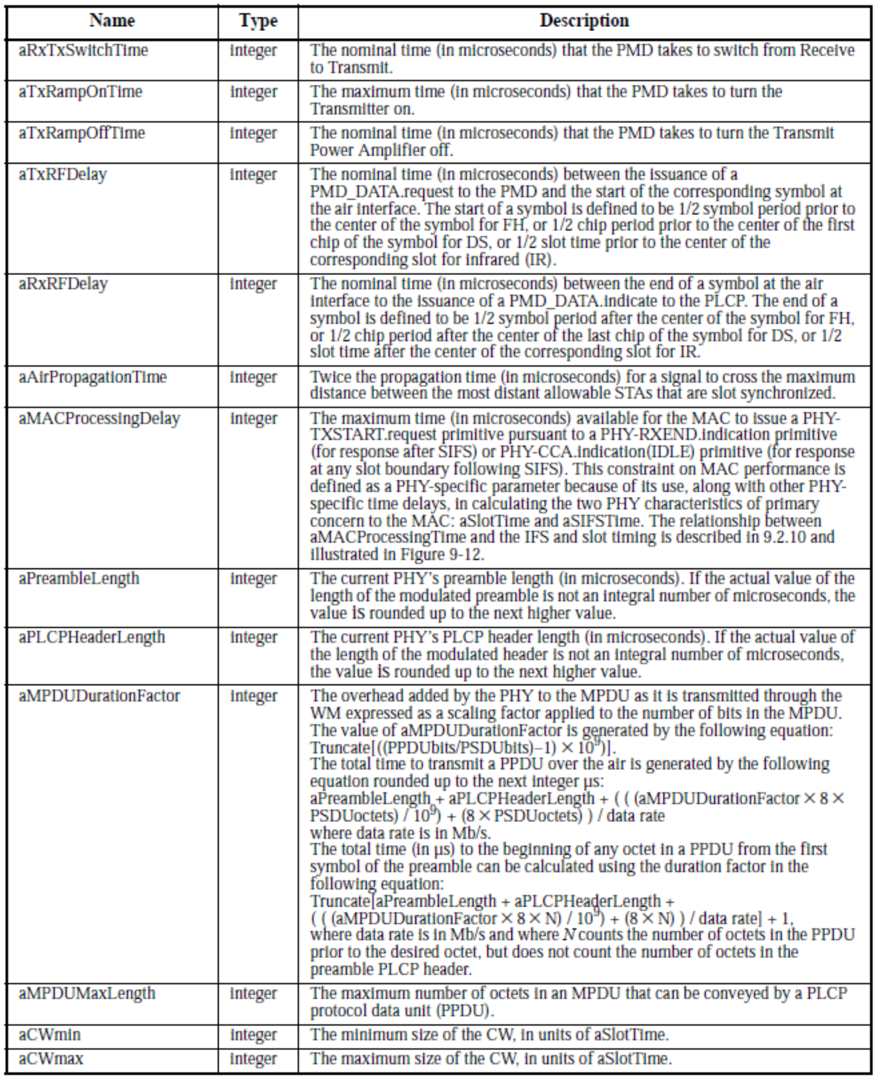
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007

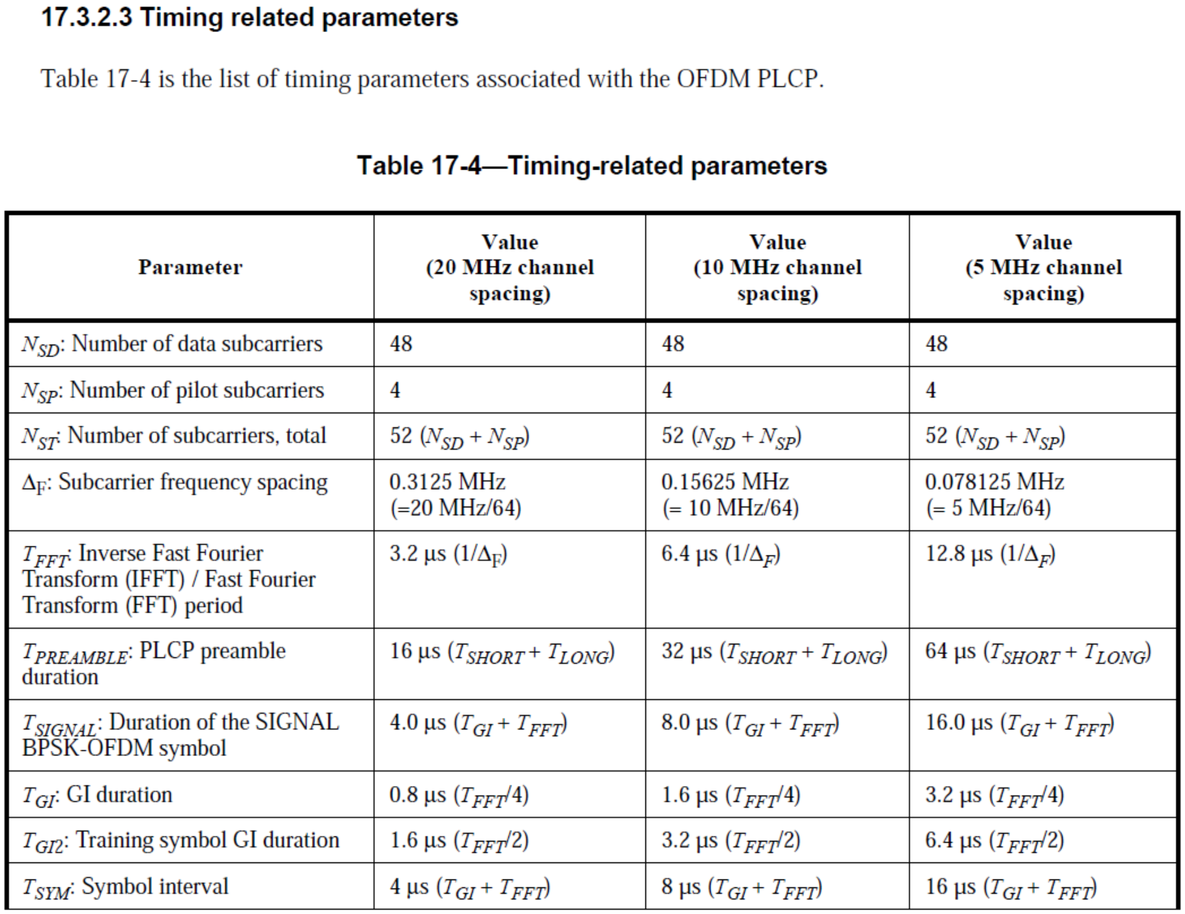


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz (=20 MHz/64)</td><td>0.15625 MHz (= 10 MHz/64)</td><td>0.078125 MHz (= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 μs ($1/\Delta_F$)</td><td>6.4 μs ($1/\Delta_F$)</td><td>12.8 μs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 μs ($T_{SHORT} + T_{LONG}$)</td><td>32 μs ($T_{SHORT} + T_{LONG}$)</td><td>64 μs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 μs ($T_{GI} + T_{FFT}$)</td><td>8.0 μs ($T_{GI} + T_{FFT}$)</td><td>16.0 μs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 μs ($T_{FFT}/4$)</td><td>1.6 μs ($T_{FFT}/4$)</td><td>3.2 μs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 μs ($T_{FFT}/2$)</td><td>3.2 μs ($T_{FFT}/2$)</td><td>6.4 μs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 μs ($T_{GI} + T_{FFT}$)</td><td>8 μs ($T_{GI} + T_{FFT}$)</td><td>16 μs ($T_{GI} + T_{FFT}$)</td></tr>
</table>
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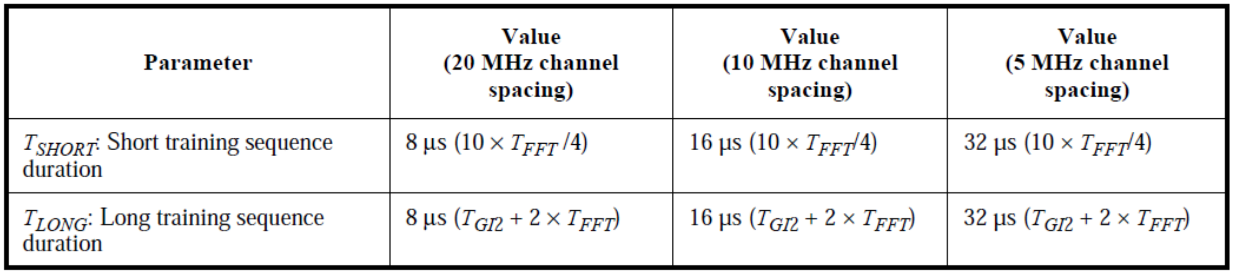
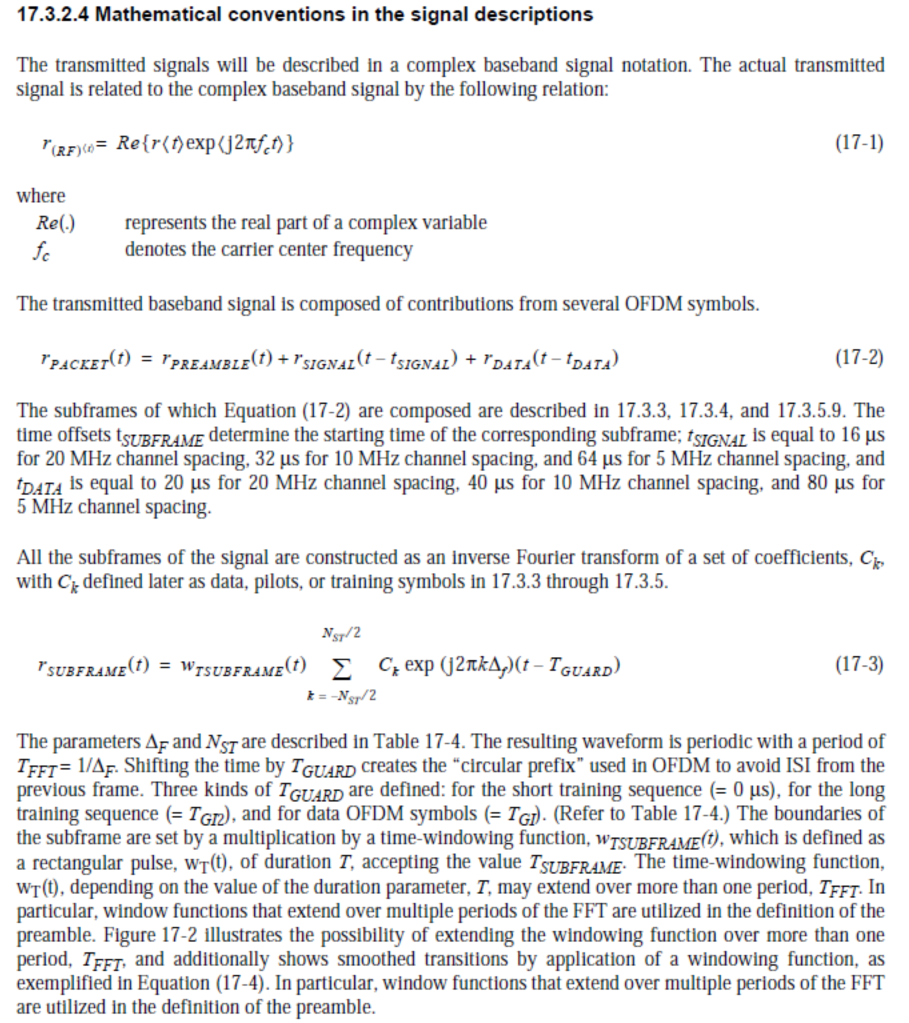
<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable
f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

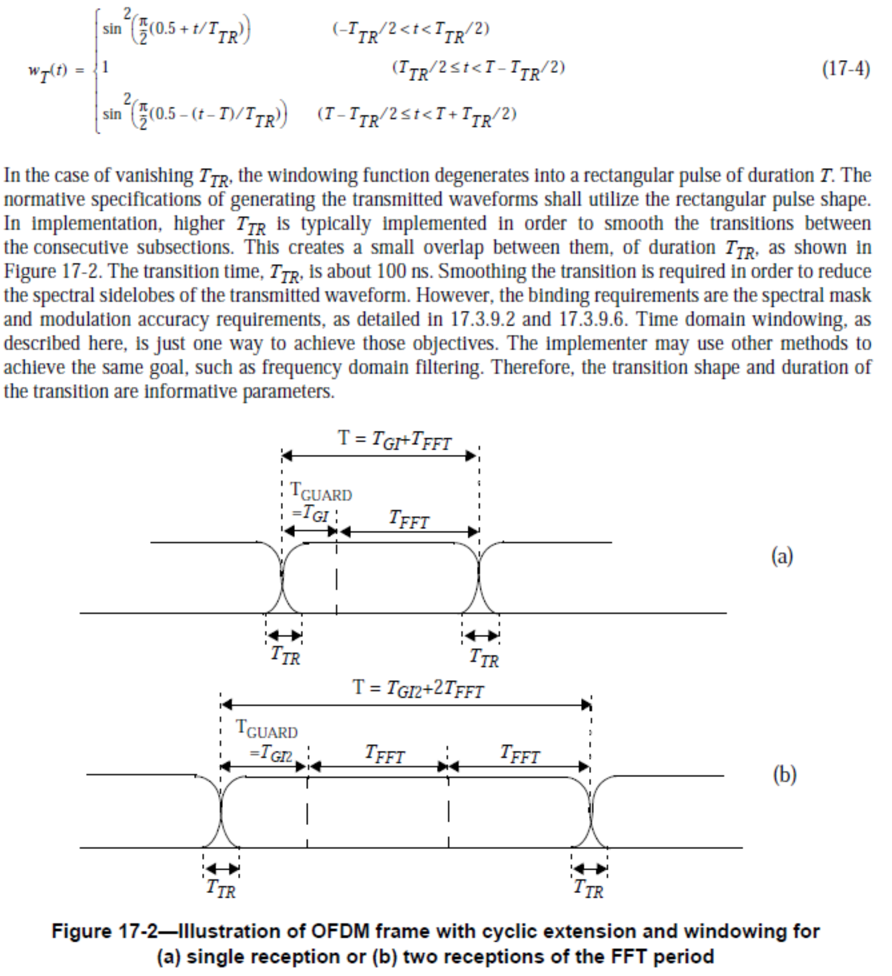
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

$$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\} \qquad (17\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

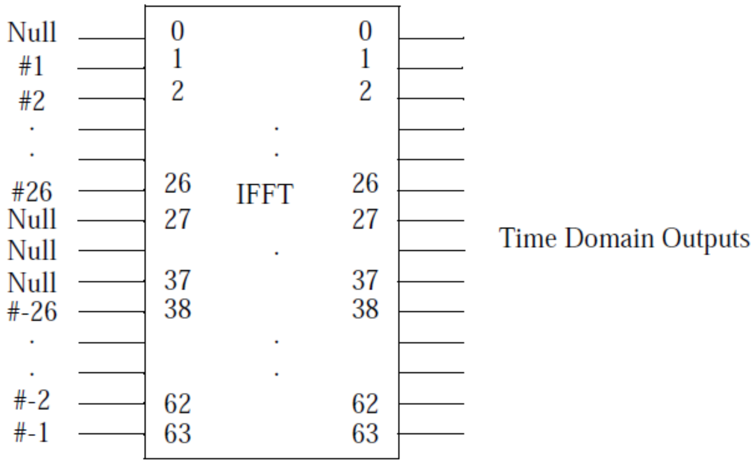
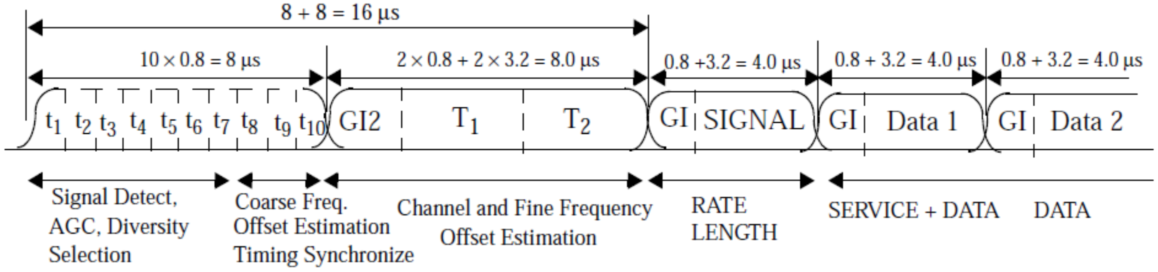


Figure 17-3—Inputs and outputs of inverse Fourier transform

See, e.g., 802.11-2007 § 17.3.2.5

</td></tr>
</table>

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

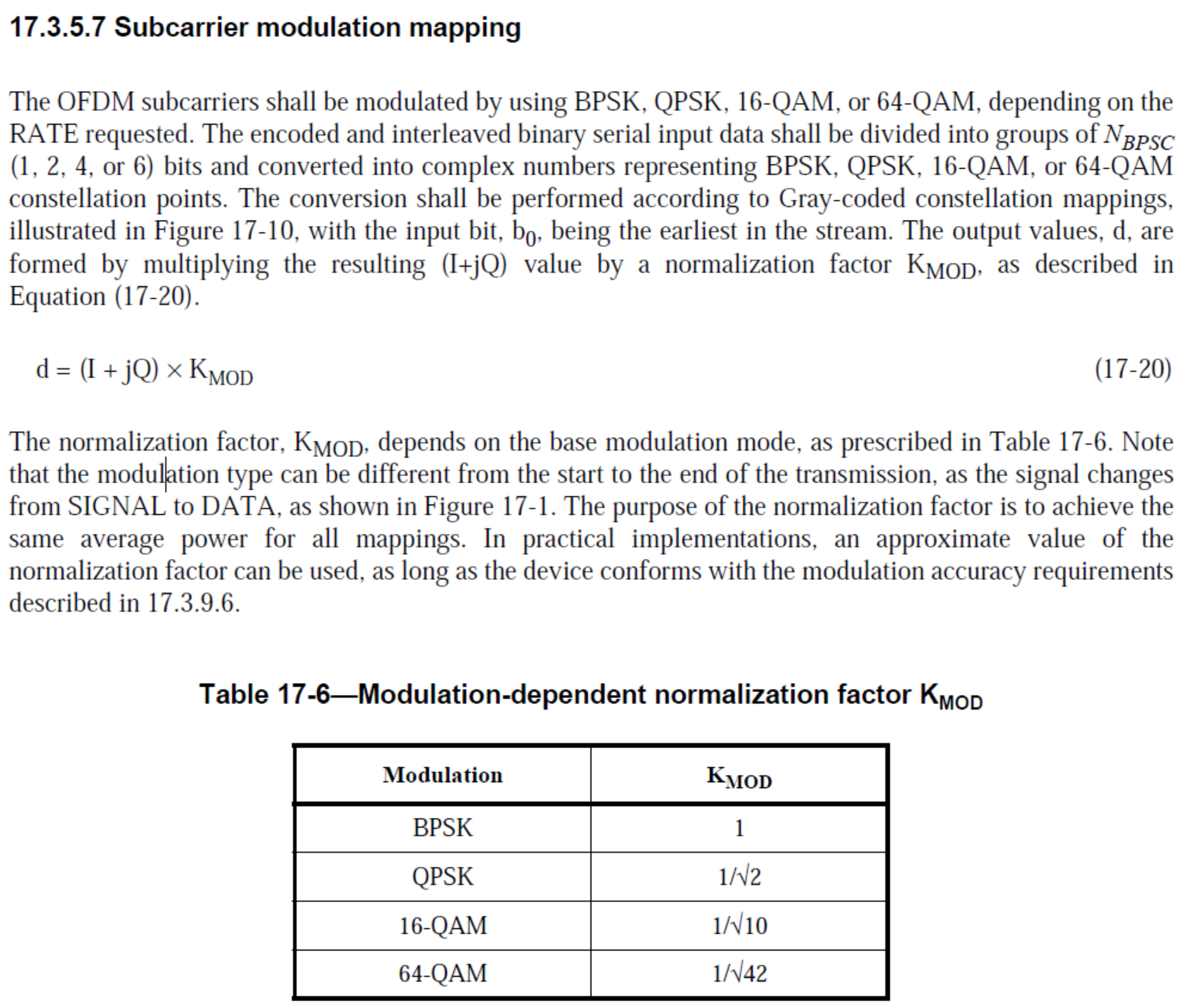
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k + N_{SD} \times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n} \exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1, \\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1, \\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1, \\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \qquad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

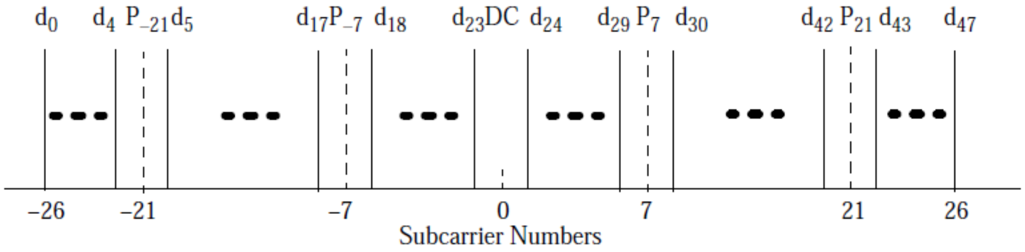


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

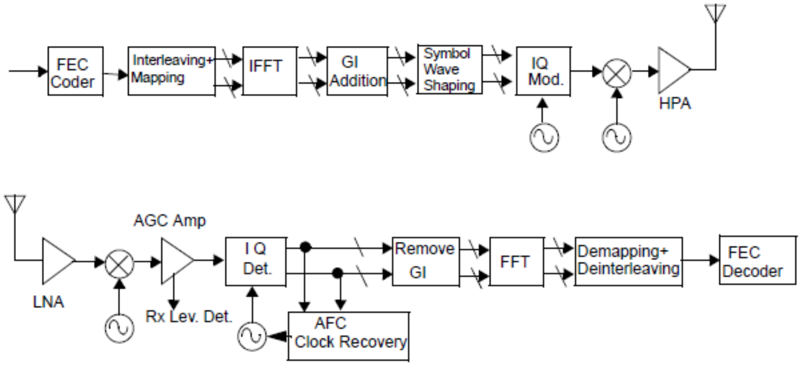


Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

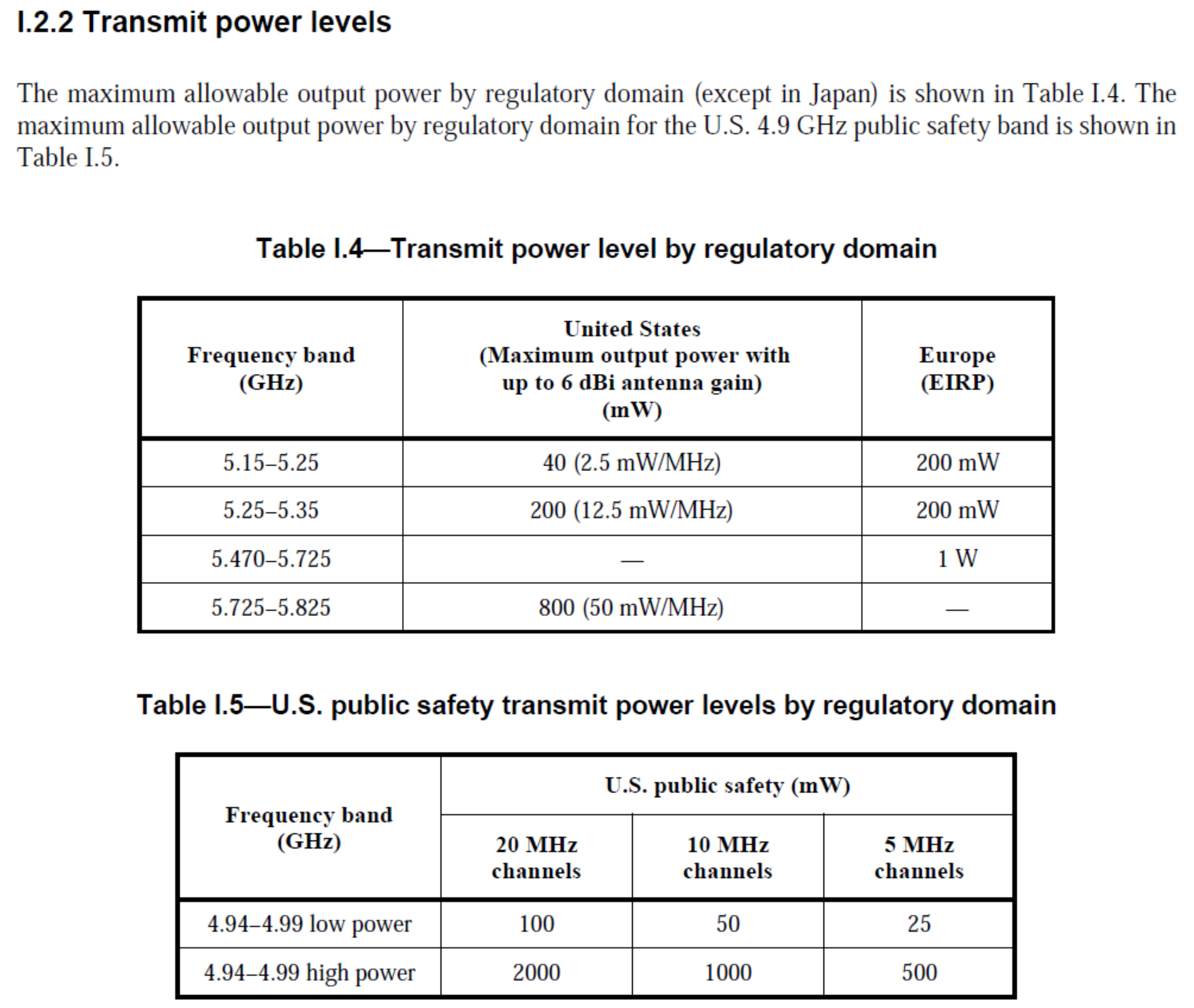
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

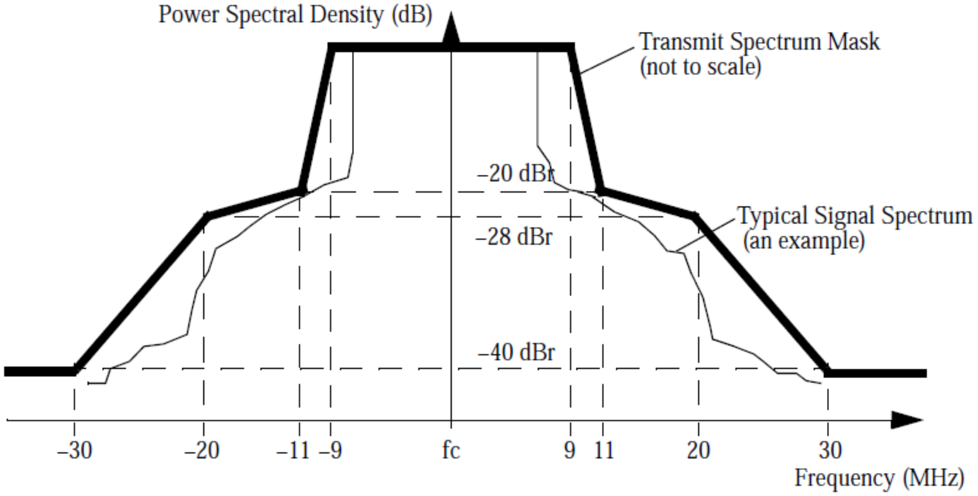
Table I.4—Transmit power level by regulatory domain

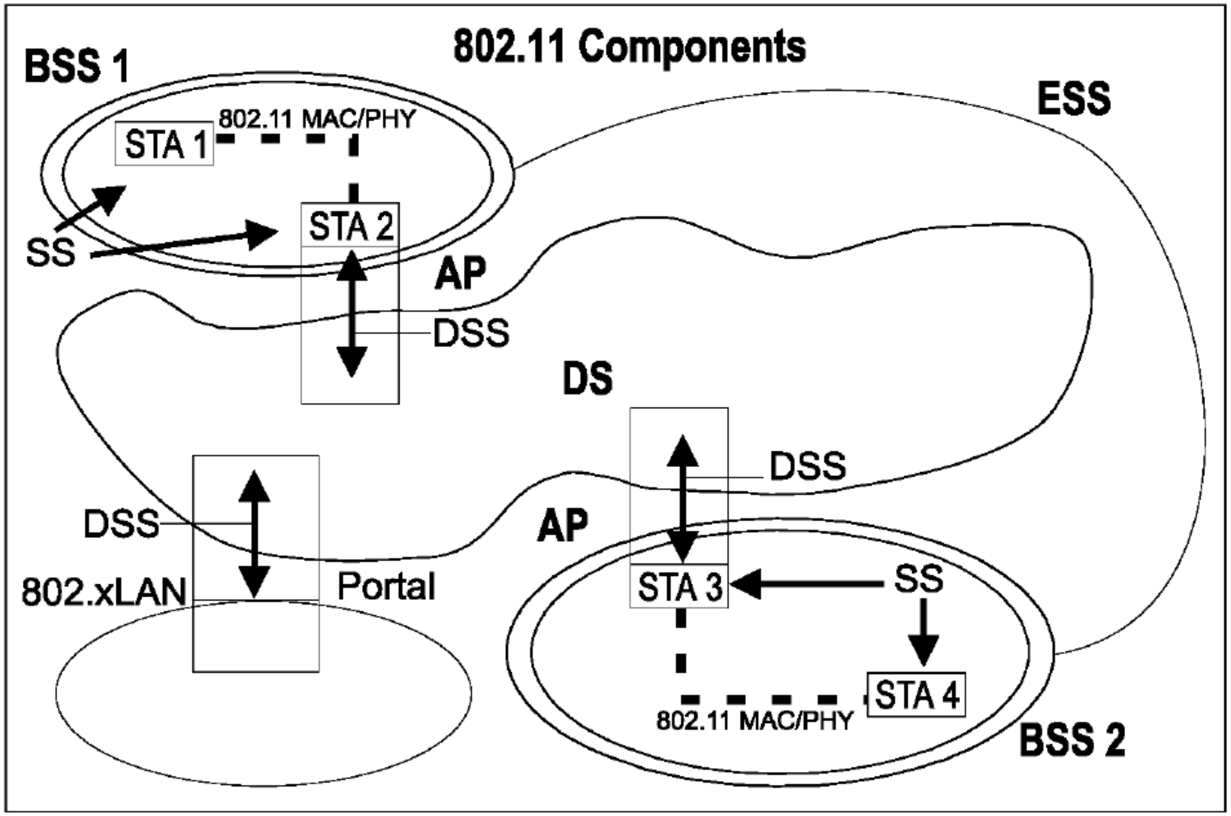
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

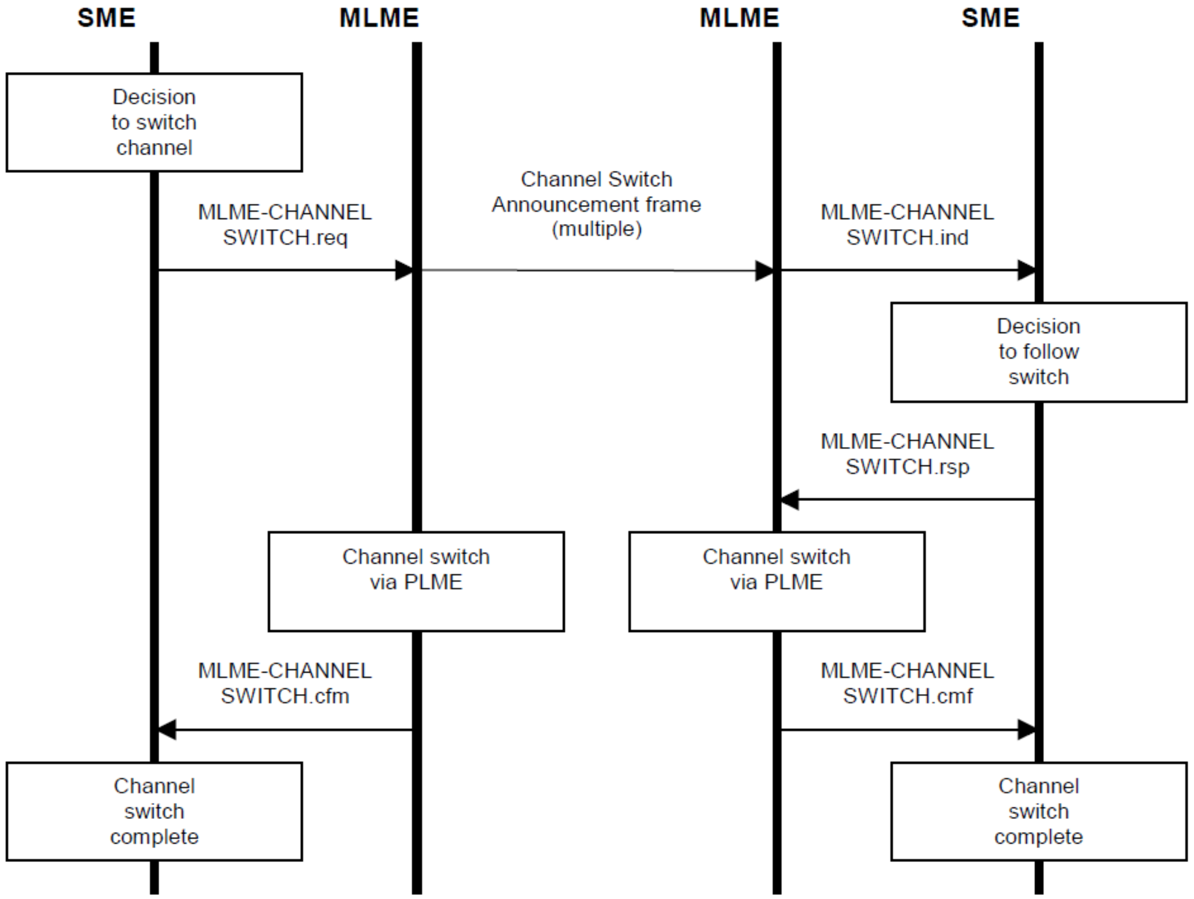
<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


Figure 10-6—Channel switch

See, e.g., 802.11-2007 Figure 10-6

Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-
</td></tr>
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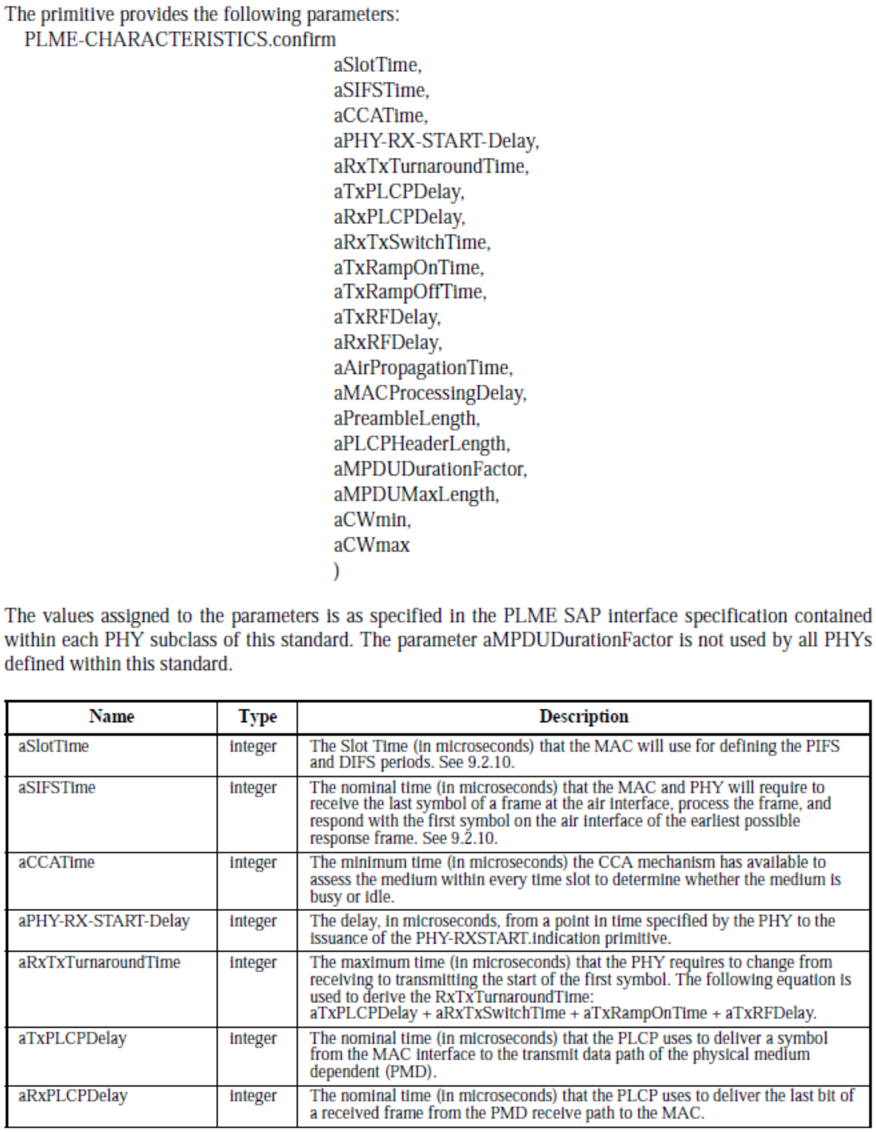
Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.3] a first digital-to-analog converter for receiving the first digital signal and converting the first digital signal into a first analog signal, the first analog signal carrying the first data across a first frequency range;	802.11-2007 discloses “a first digital-to-analog converter for receiving the first digital signal and converting the first digital signal into a first analog signal, the first analog signal carrying the first data across a first frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive



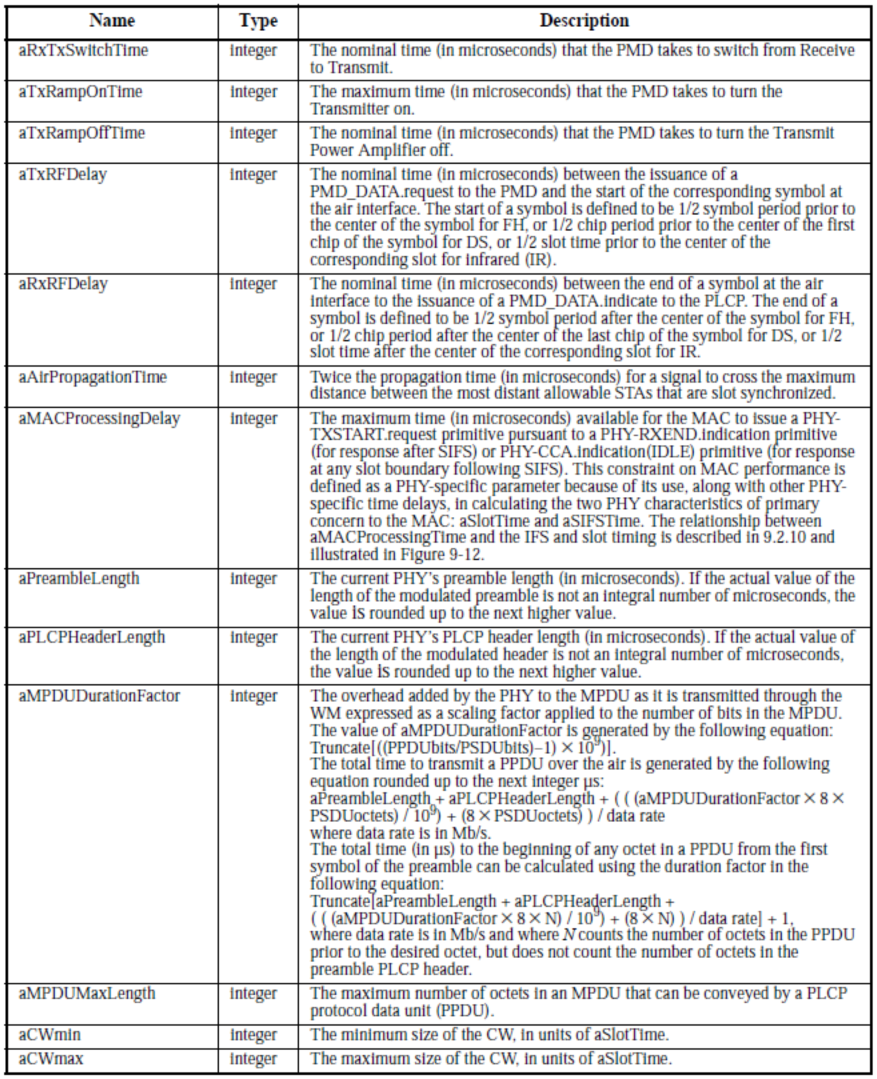
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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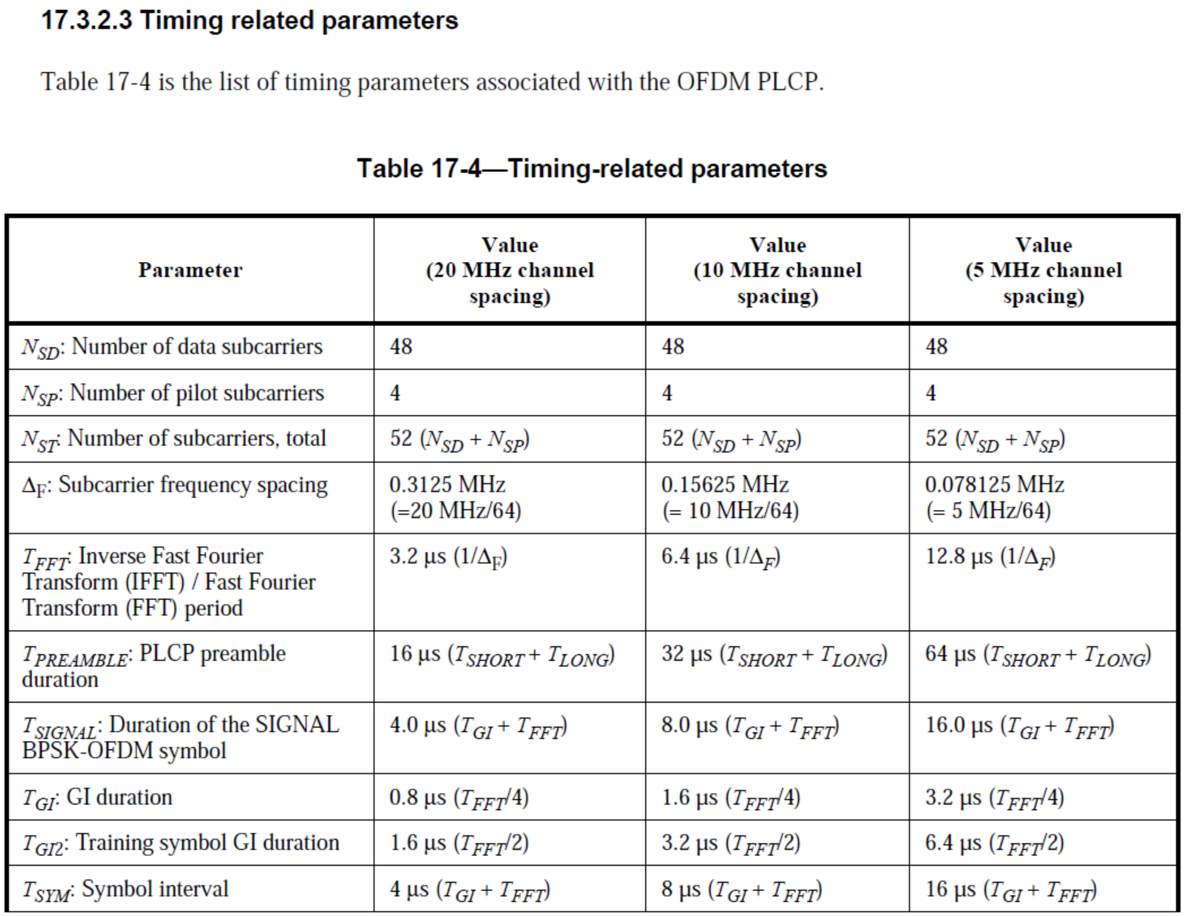
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



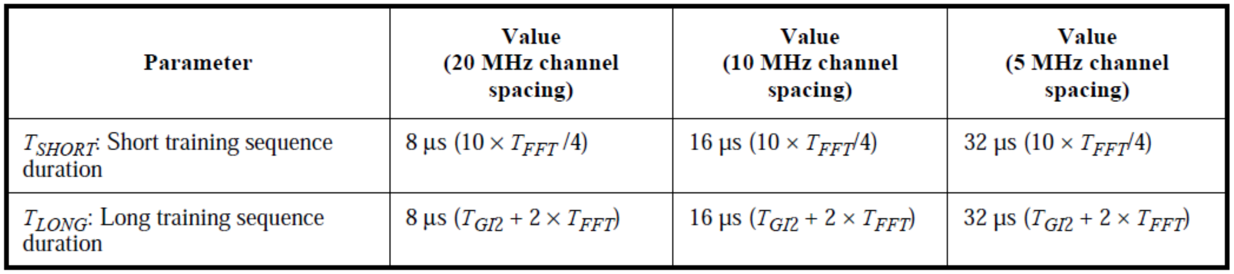
<h3>17.3.2.3 Timing related parameters</h3>

<p>Table 17-4 is the list of timing parameters associated with the OFDM PLCP.</p>

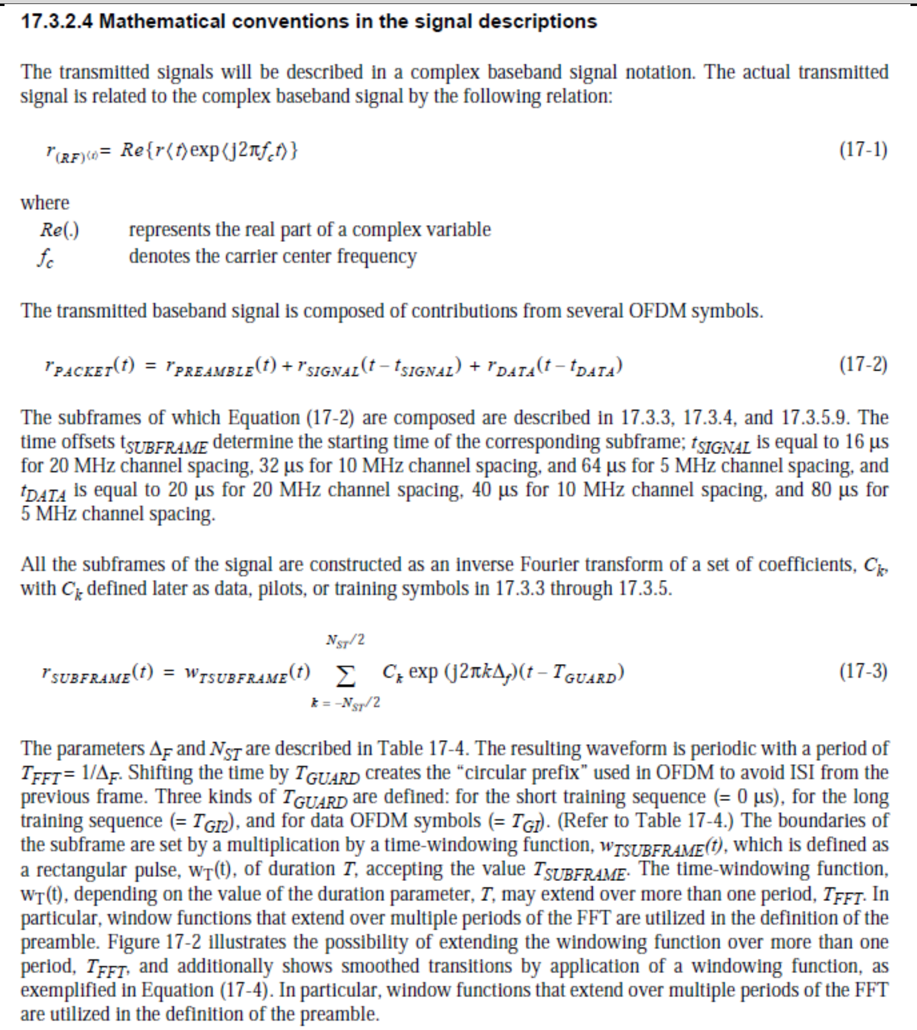
<p>Table 17-4—Timing-related parameters</p>

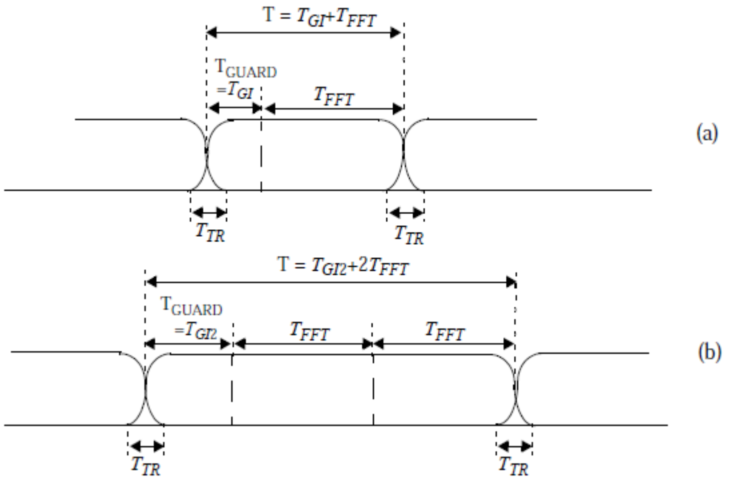
<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz
(=20 MHz/64)</td><td>0.15625 MHz
(= 10 MHz/64)</td><td>0.078125 MHz
(= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 µs ($1/\Delta_F$)</td><td>6.4 µs ($1/\Delta_F$)</td><td>12.8 µs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 µs ($T_{SHORT} + T_{LONG}$)</td><td>32 µs ($T_{SHORT} + T_{LONG}$)</td><td>64 µs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 µs ($T_{GI} + T_{FFT}$)</td><td>8.0 µs ($T_{GI} + T_{FFT}$)</td><td>16.0 µs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 µs ($T_{FFT}/4$)</td><td>1.6 µs ($T_{FFT}/4$)</td><td>3.2 µs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 µs ($T_{FFT}/2$)</td><td>3.2 µs ($T_{FFT}/2$)</td><td>6.4 µs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 µs ($T_{GI} + T_{FFT}$)</td><td>8 µs ($T_{GI} + T_{FFT}$)</td><td>16 µs ($T_{GI} + T_{FFT}$)</td></tr>
</table>

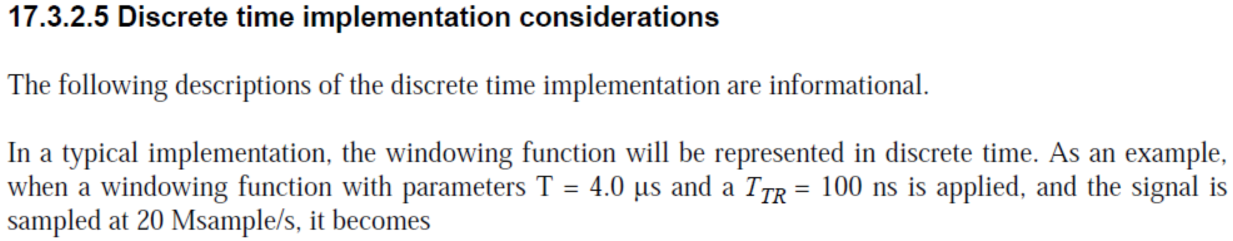
</td></tr>
</table>

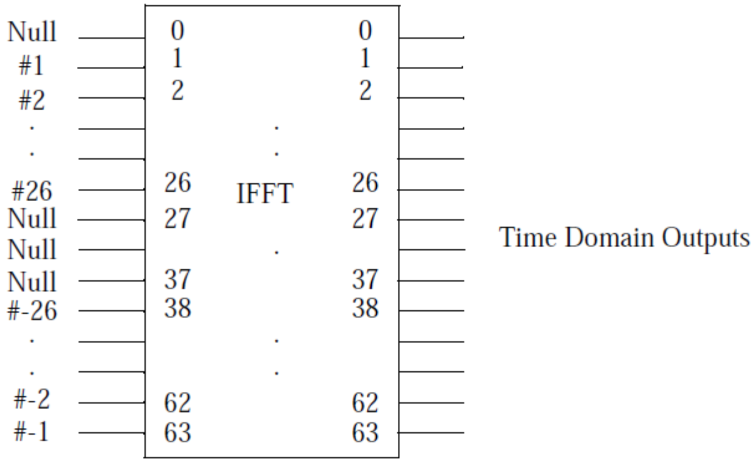
<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)(t)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

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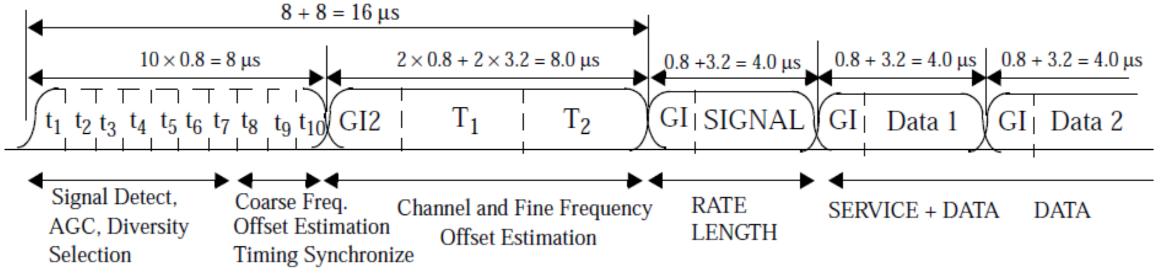
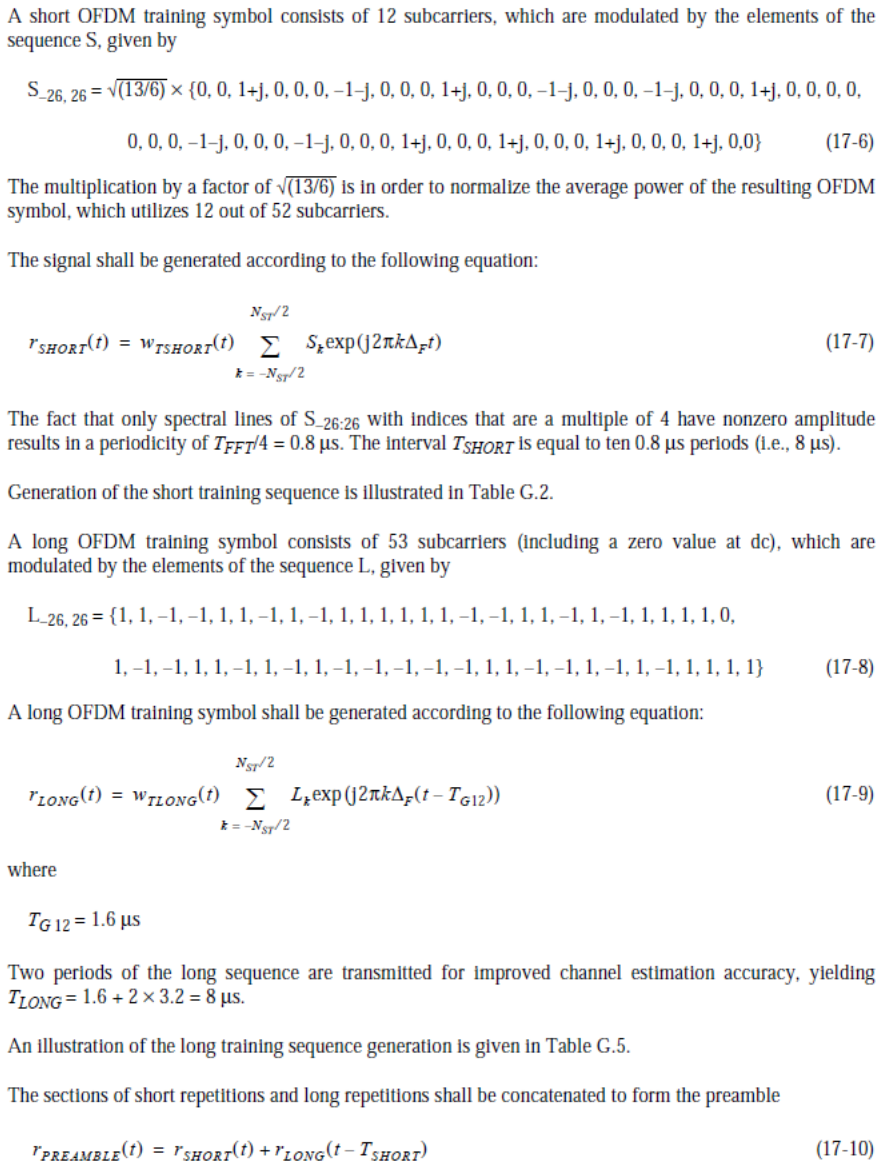
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

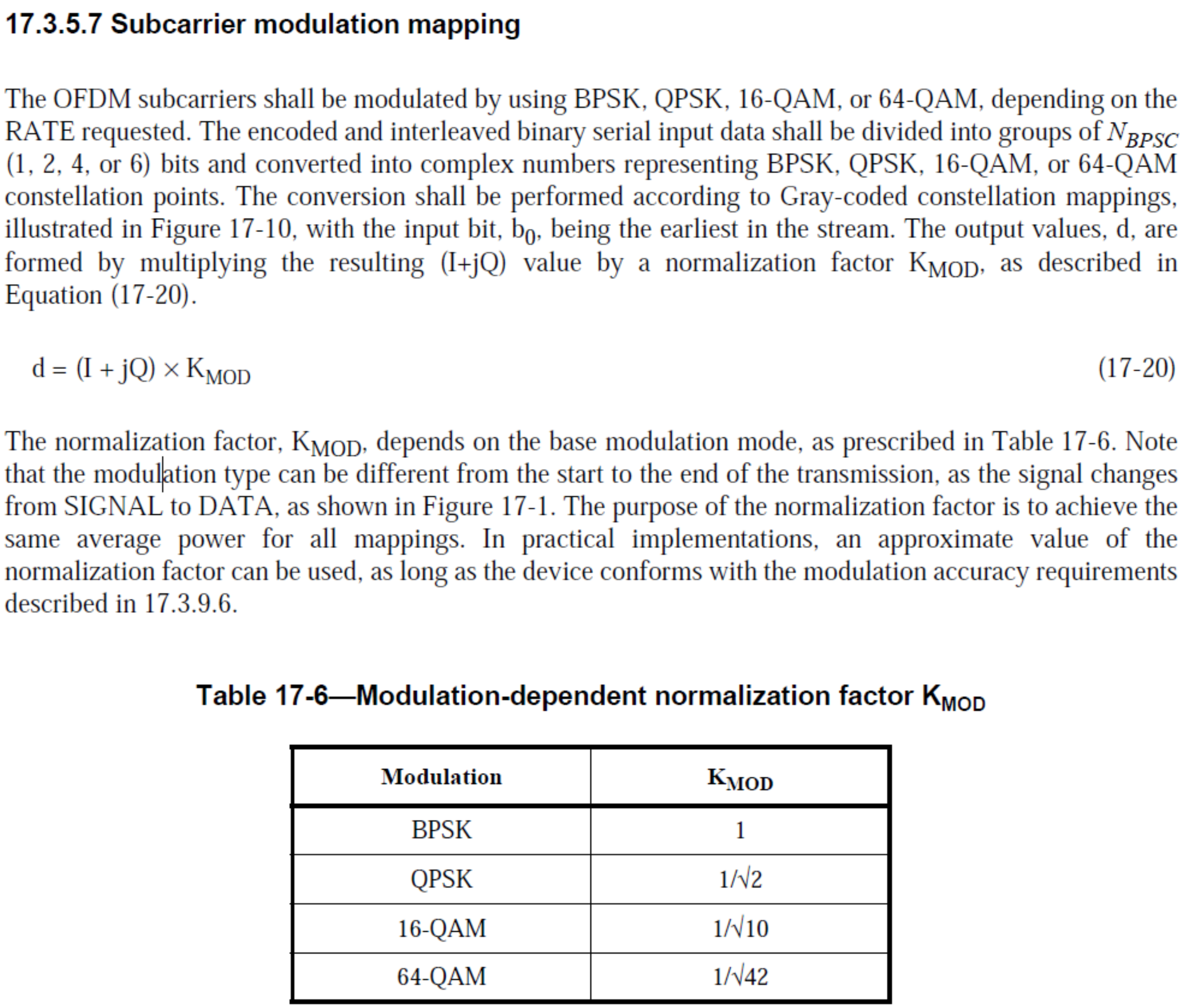
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

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	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \dots N_{SD}-1,\ n = 0, \dots N_{SYM}-1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the nth OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,$$
$$1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,$$
$$-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,$$
$$-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \qquad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

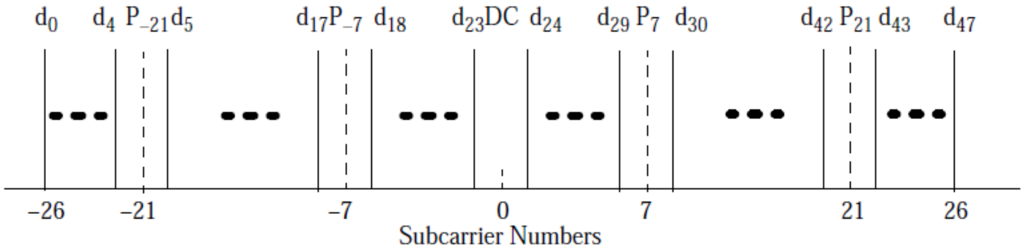


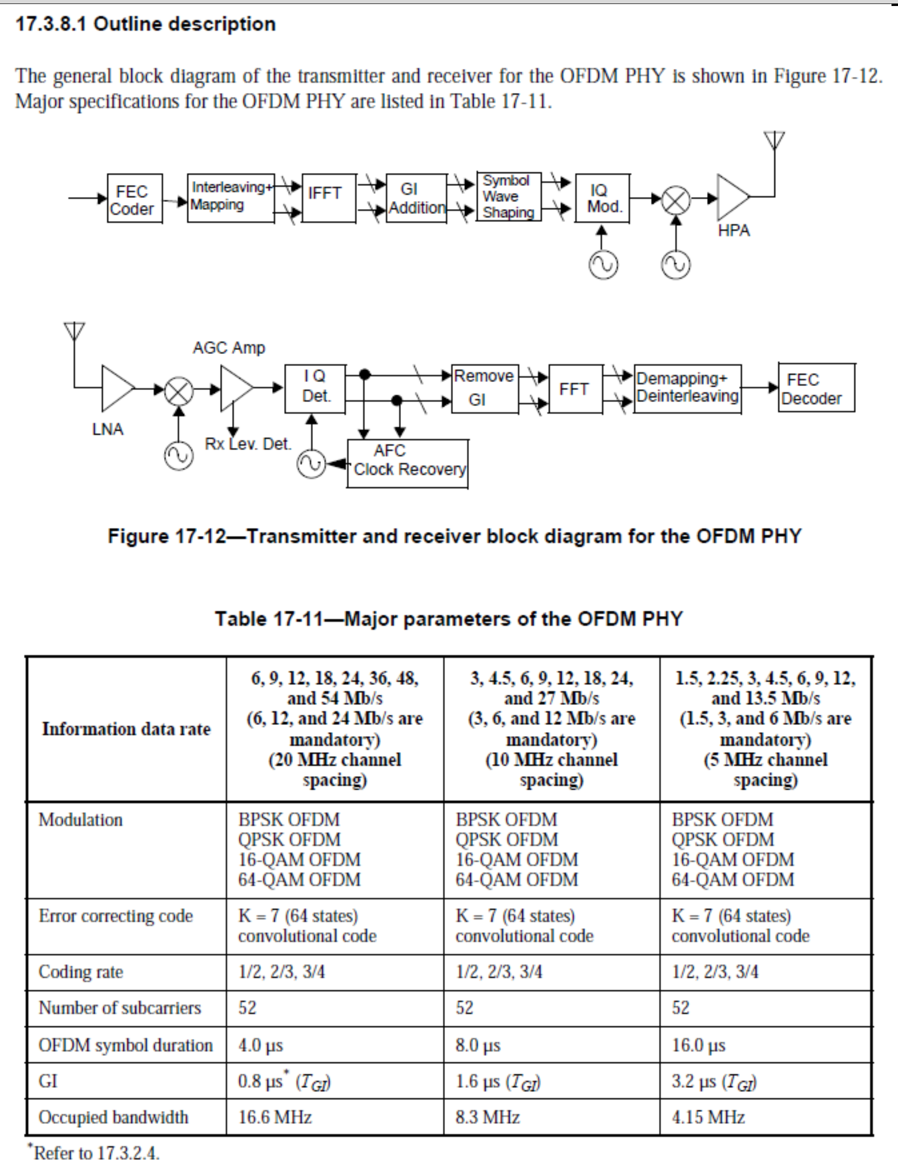
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

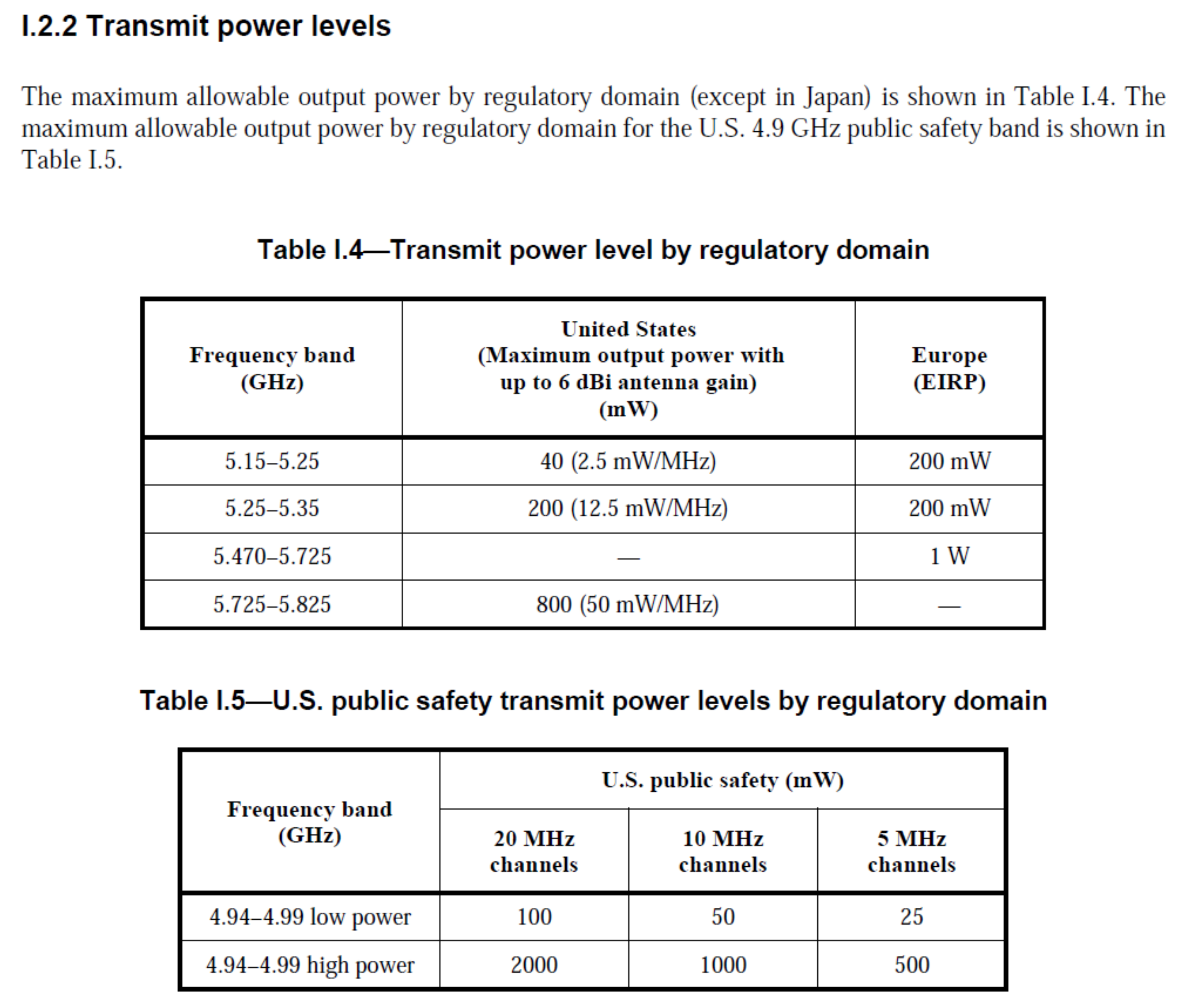
Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

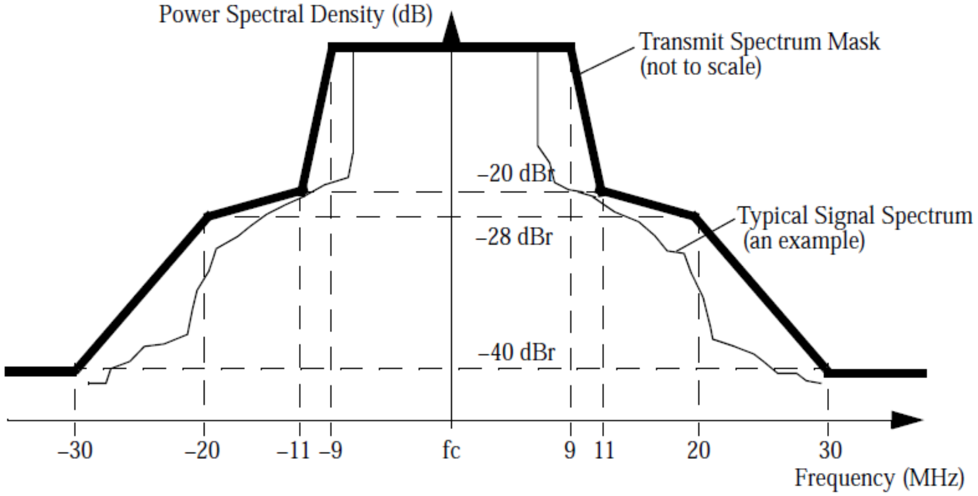
Table I.4—Transmit power level by regulatory domain

Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

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<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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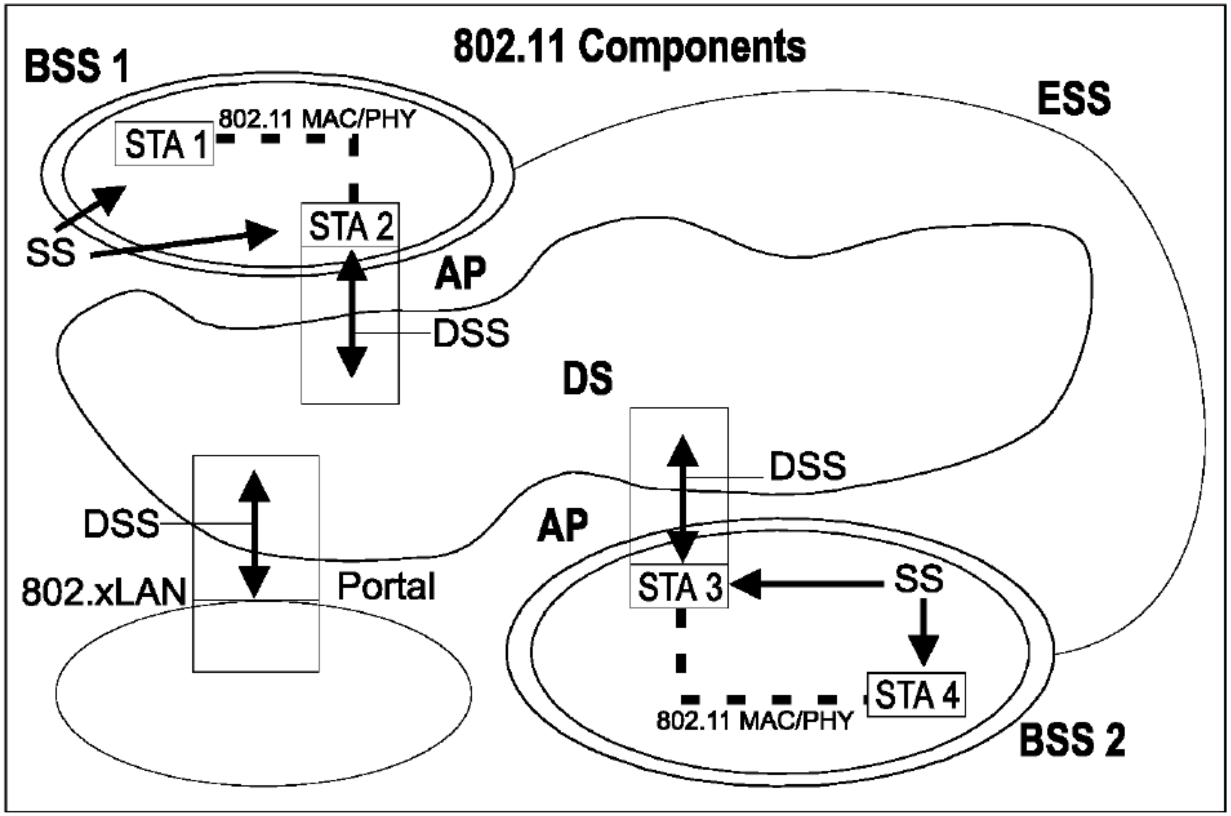

Figure 5-7—Complete IEEE 802.11 architecture

See, e.g., 802.11-2007 Figure 5-7
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<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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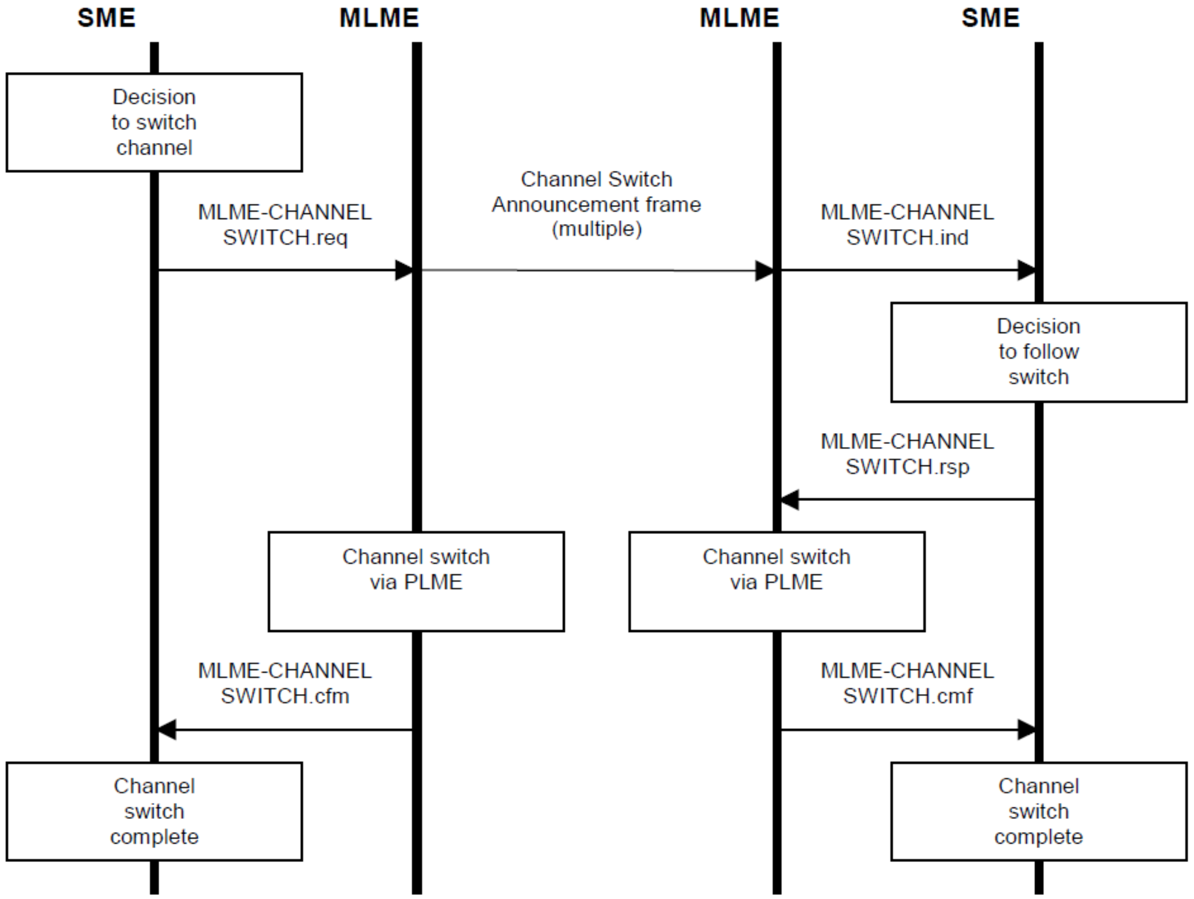

Figure 10-6—Channel switch

See, e.g., 802.11-2007 Figure 10-6

Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-
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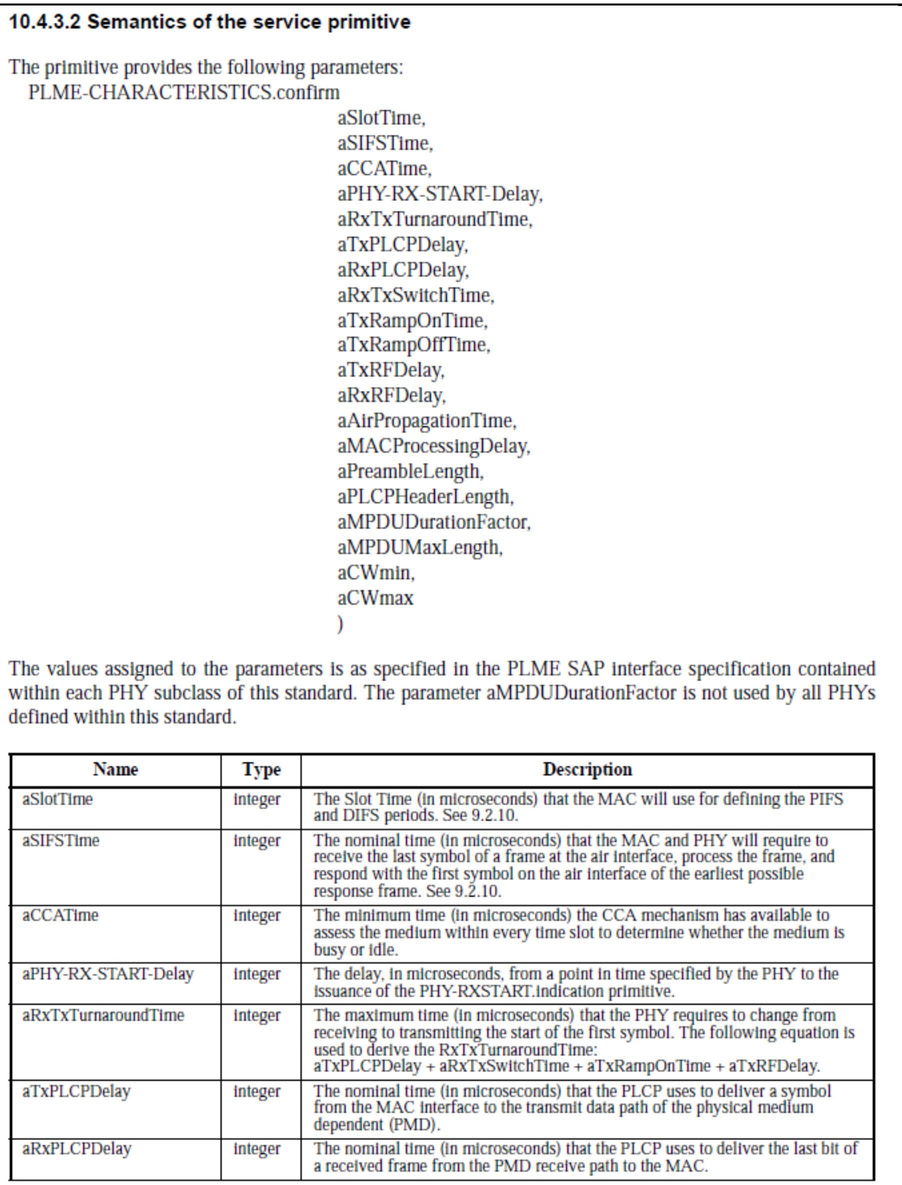
Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.4] a second digital-to-analog converter for receiving the second digital signal and converting the second digital signal into a second analog signal, the second analog signal carrying the second data across a second frequency range;	802.11-2007 discloses “a second digital-to-analog converter for receiving the second digital signal and converting the second digital signal into a second analog signal, the second analog signal carrying the second data across a second frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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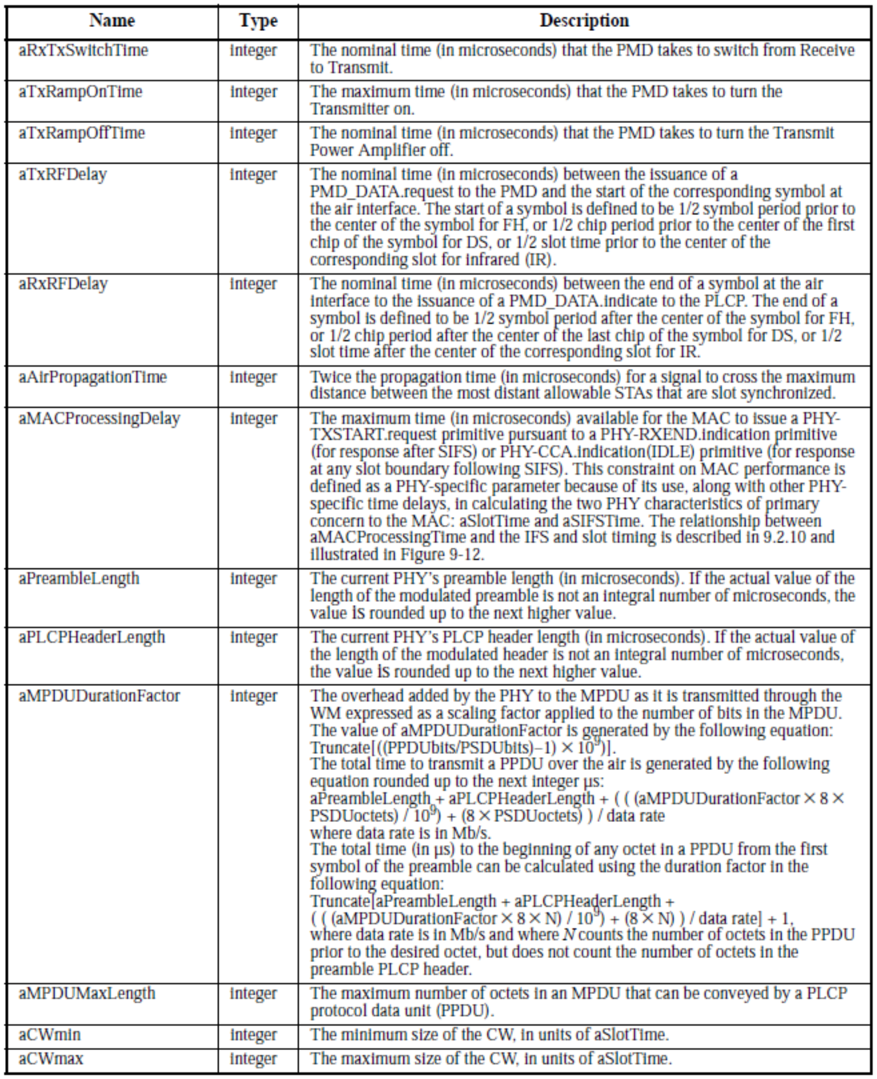

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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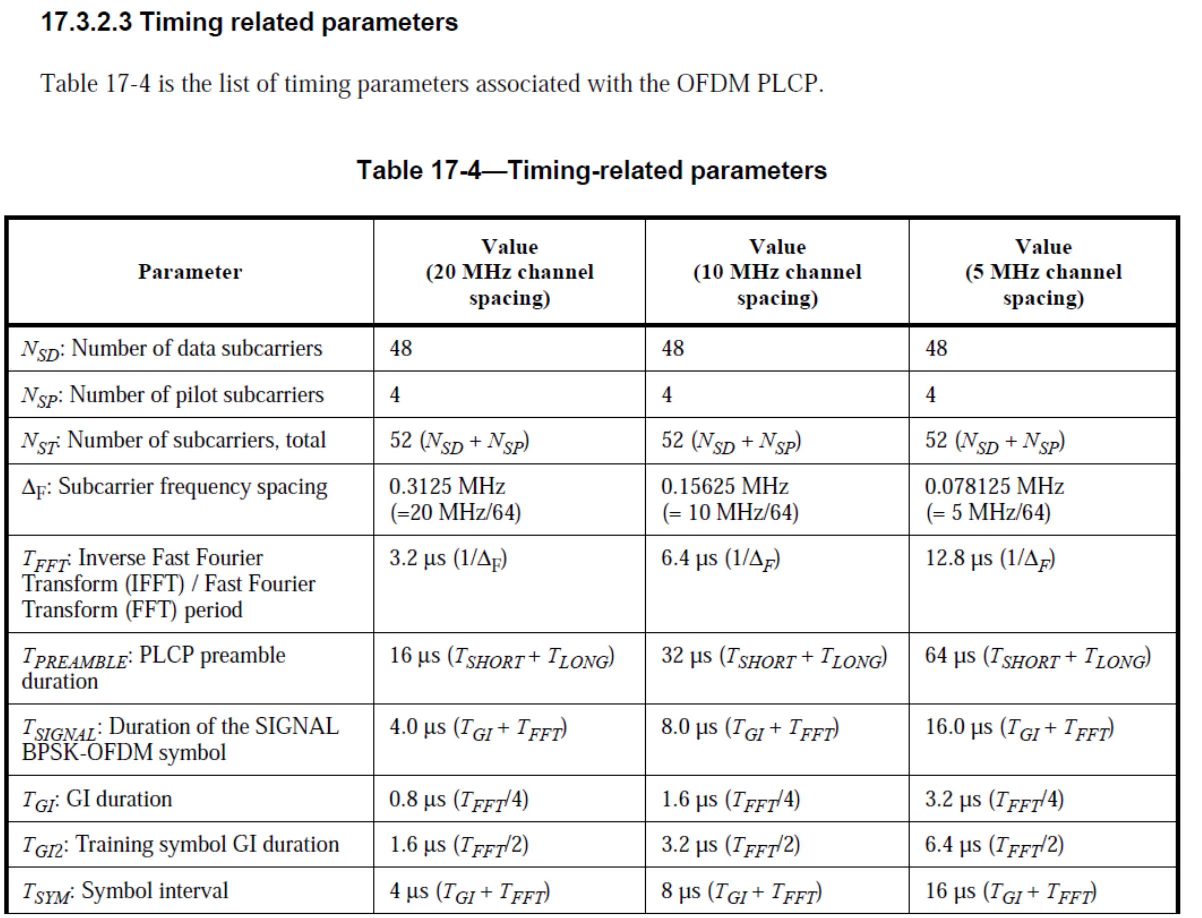

17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz (=20 MHz/64)</td><td>0.15625 MHz (= 10 MHz/64)</td><td>0.078125 MHz (= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 µs ($1/\Delta_F$)</td><td>6.4 µs ($1/\Delta_F$)</td><td>12.8 µs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 µs ($T_{SHORT} + T_{LONG}$)</td><td>32 µs ($T_{SHORT} + T_{LONG}$)</td><td>64 µs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 µs ($T_{GI} + T_{FFT}$)</td><td>8.0 µs ($T_{GI} + T_{FFT}$)</td><td>16.0 µs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 µs ($T_{FFT}/4$)</td><td>1.6 µs ($T_{FFT}/4$)</td><td>3.2 µs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 µs ($T_{FFT}/2$)</td><td>3.2 µs ($T_{FFT}/2$)</td><td>6.4 µs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 µs ($T_{GI} + T_{FFT}$)</td><td>8 µs ($T_{GI} + T_{FFT}$)</td><td>16 µs ($T_{GI} + T_{FFT}$)</td></tr>
</table>
</td></tr>
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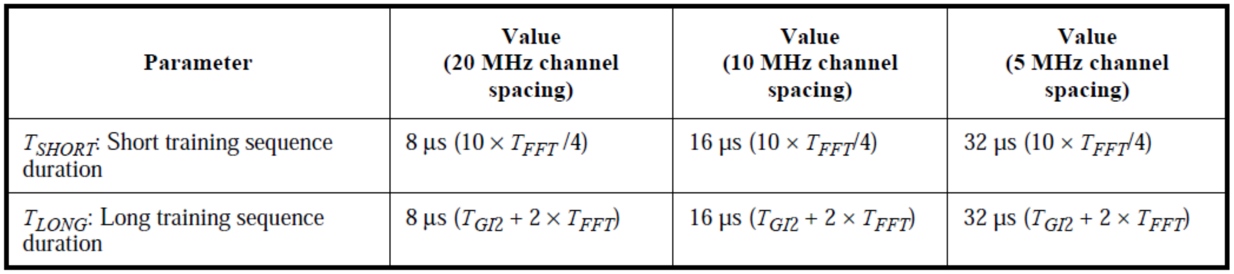
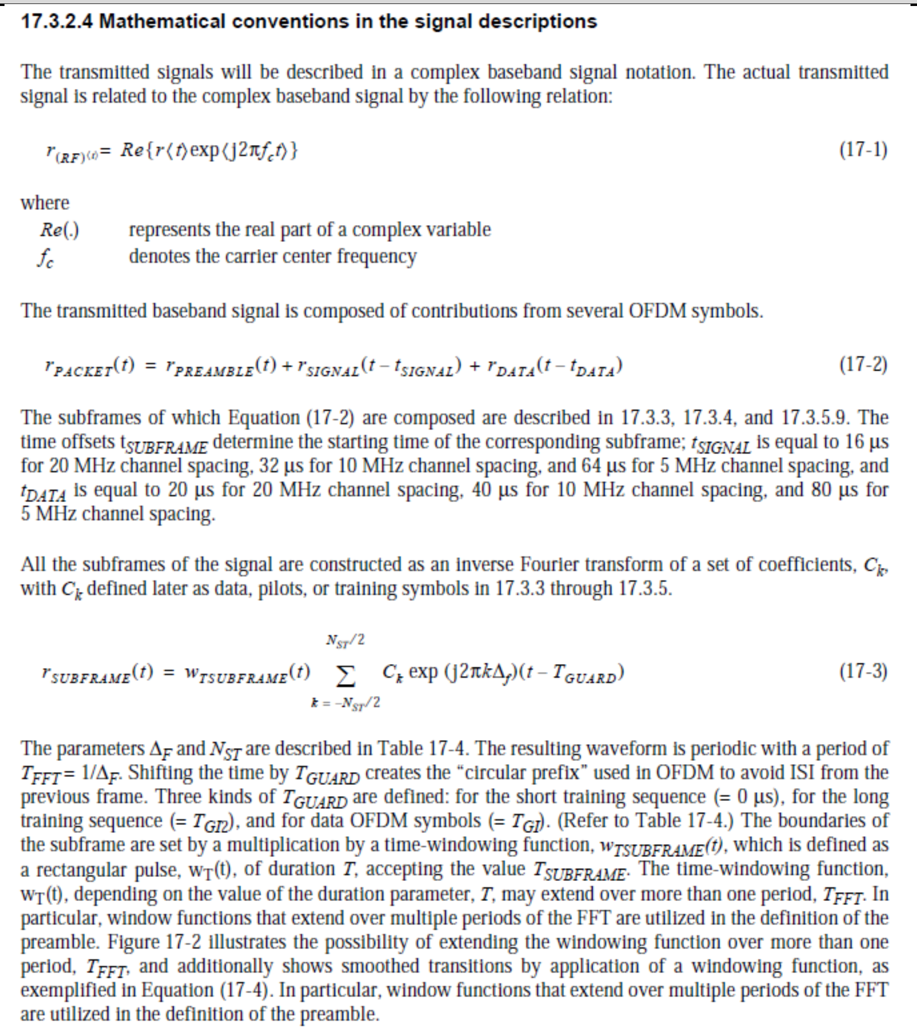
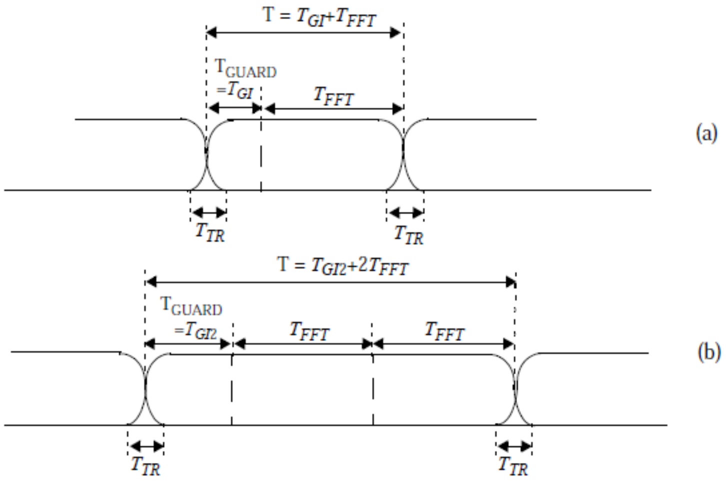
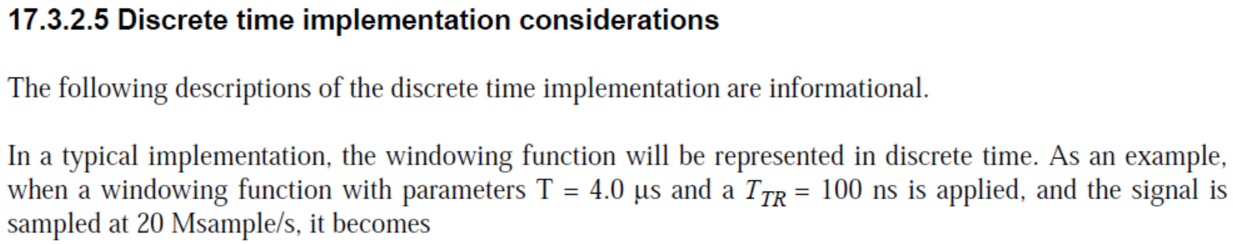
<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \qquad (17\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

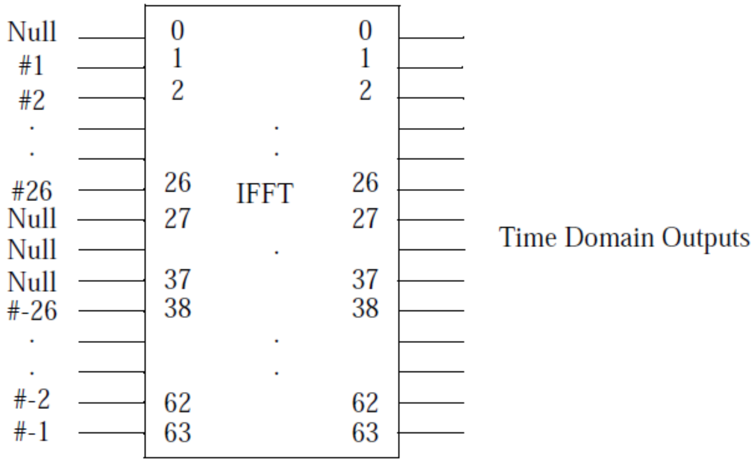
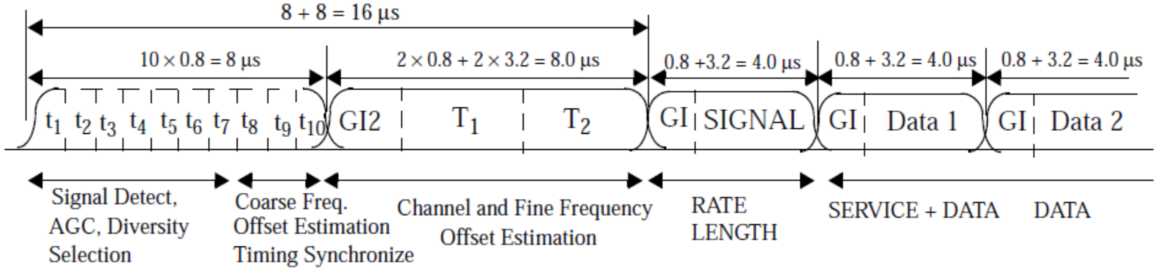
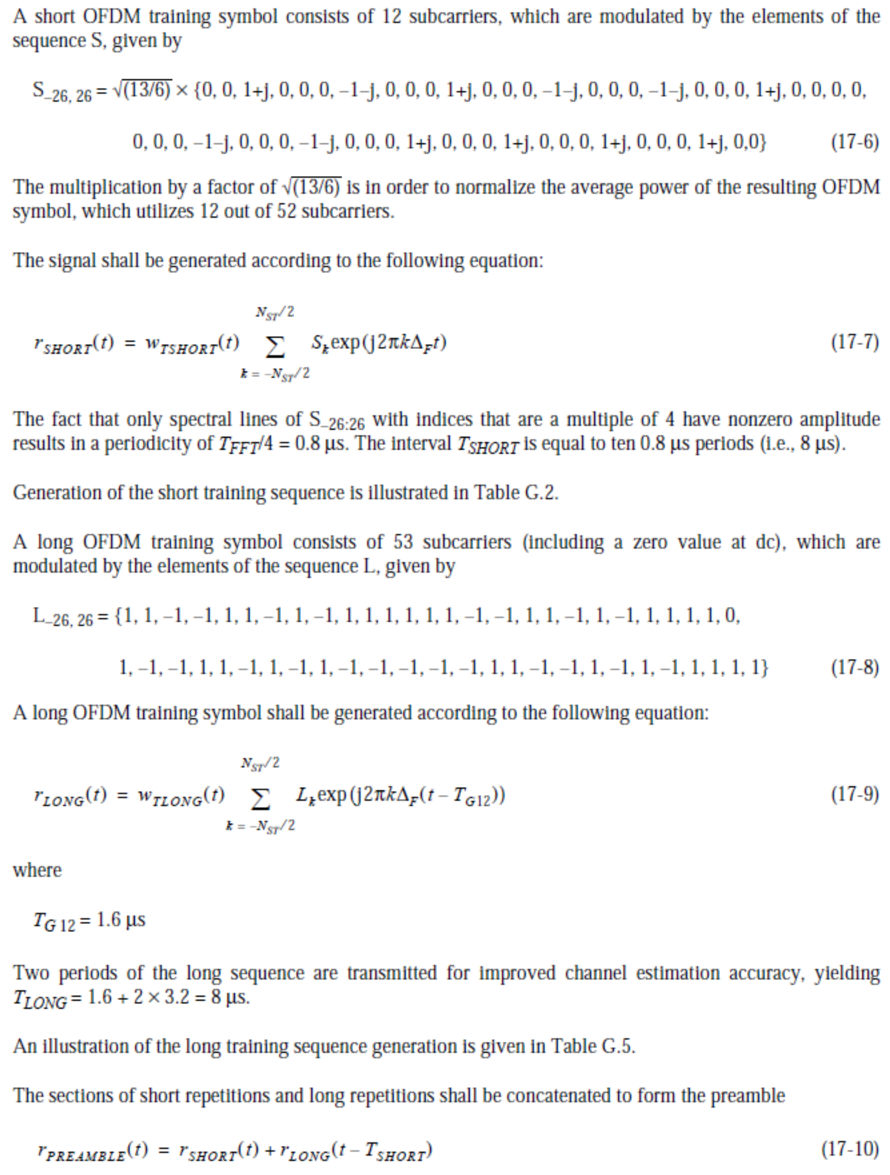


Figure 17-3—Inputs and outputs of inverse Fourier transform

See, e.g., 802.11-2007 § 17.3.2.5

</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

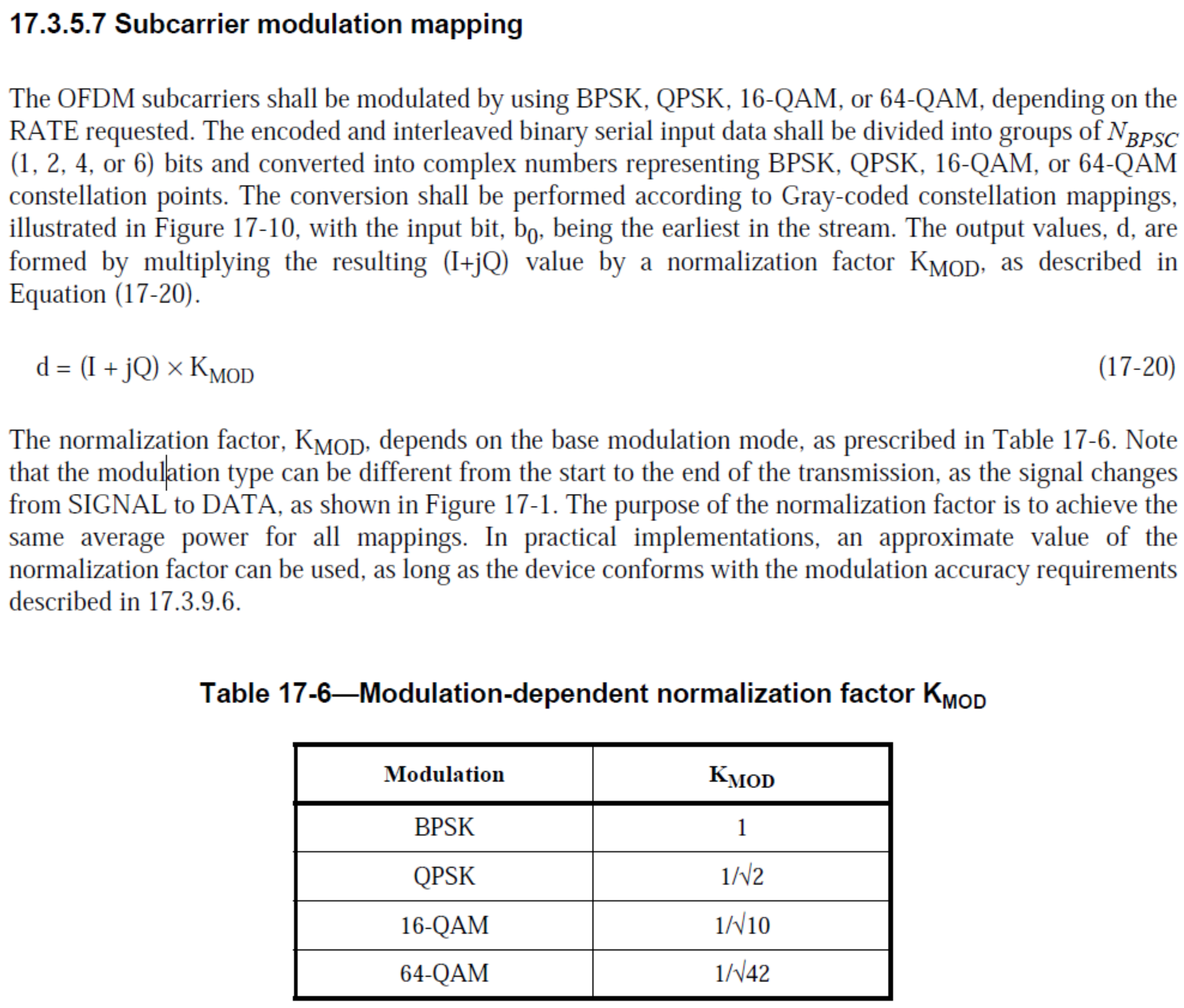
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k + N_{SD} \times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \qquad (17\text{-}21)$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n} \exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1} \sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k \Delta_F(t - T_{GI}))\right) \qquad (17\text{-}22)$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \qquad (17\text{-}23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \qquad (17\text{-}24)$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

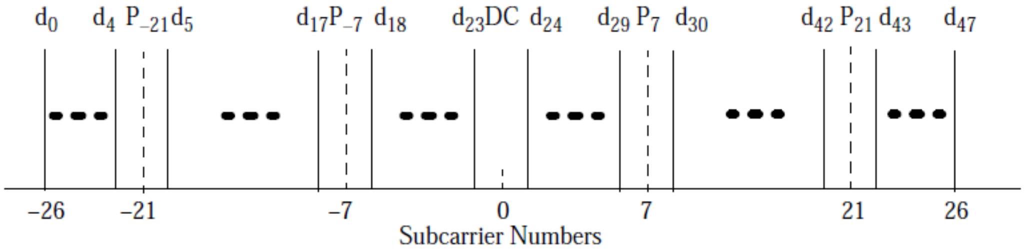


Figure 17-11—Subcarrier frequency allocation

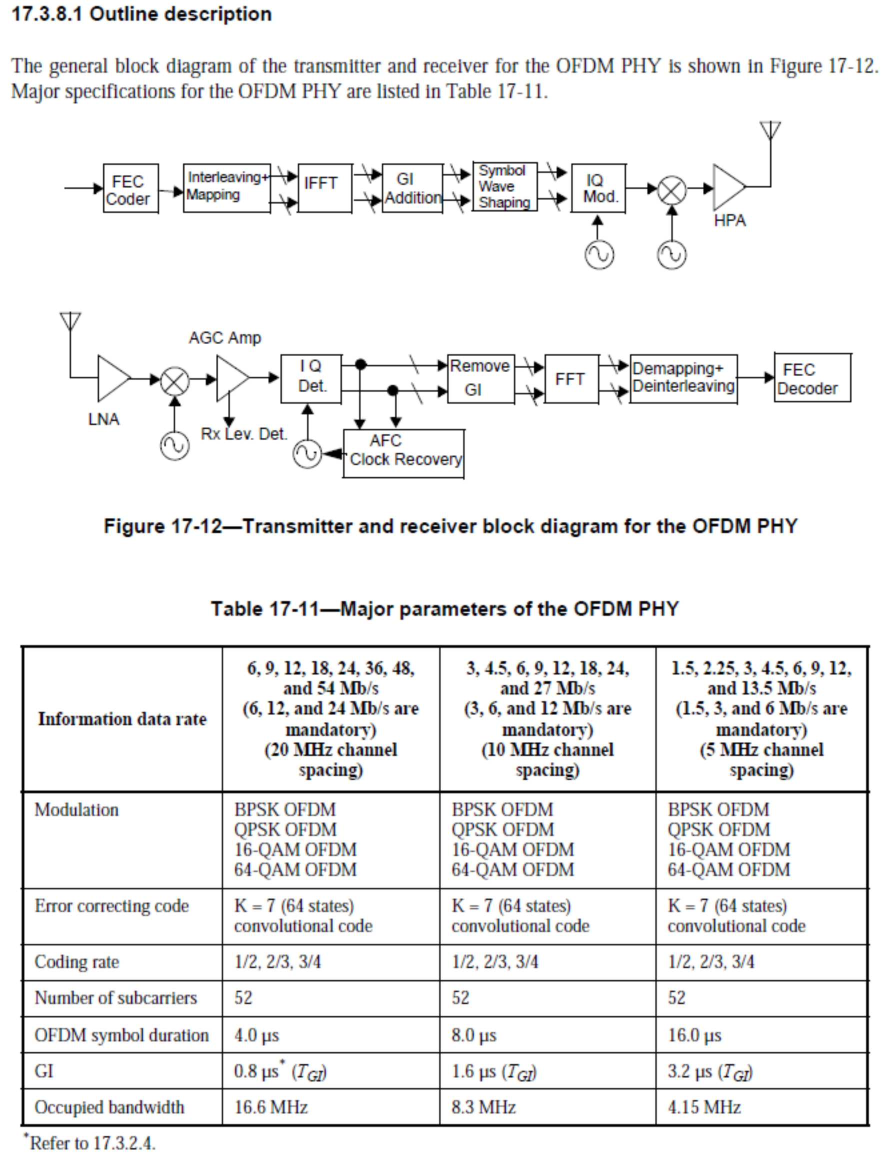
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

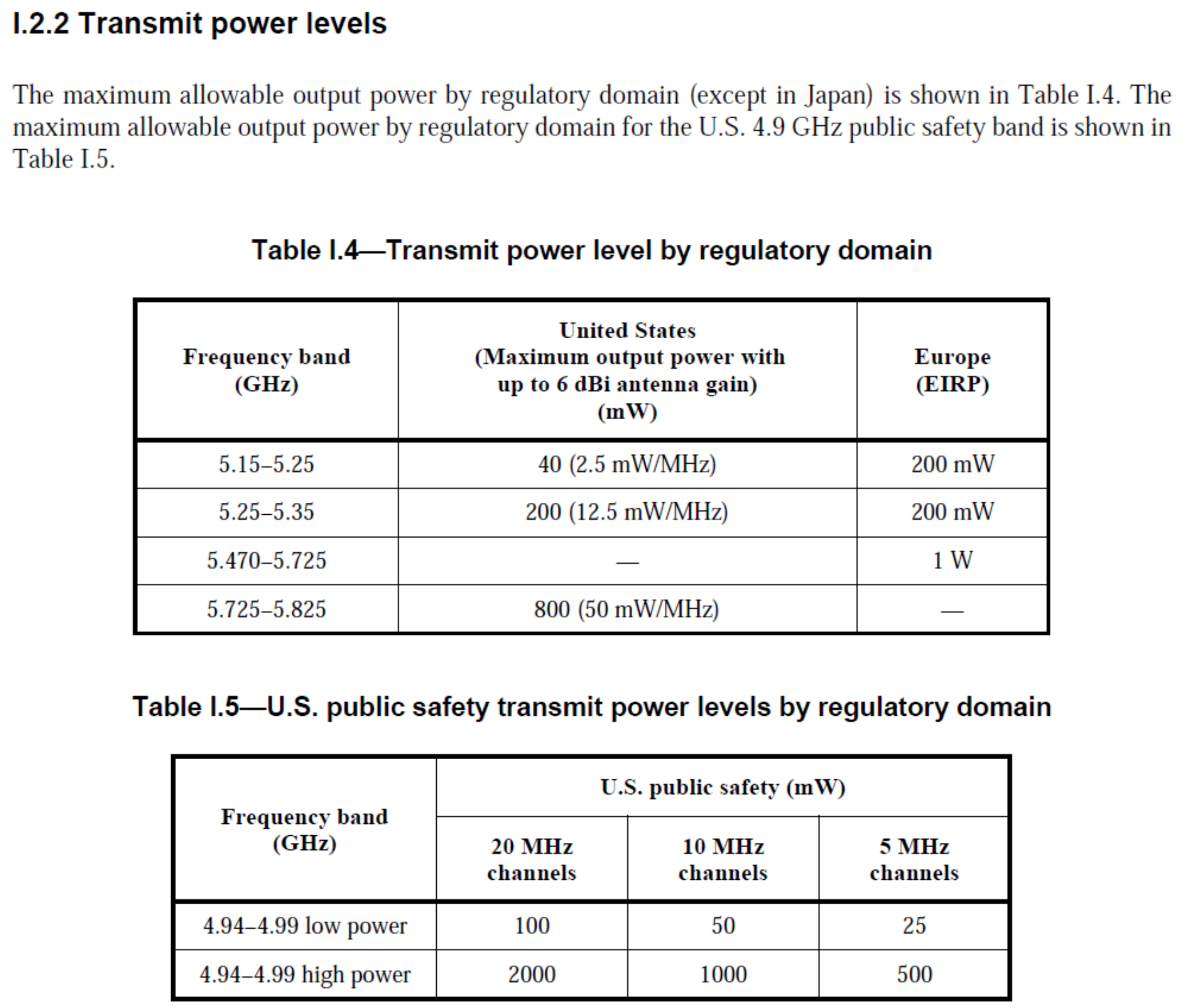
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

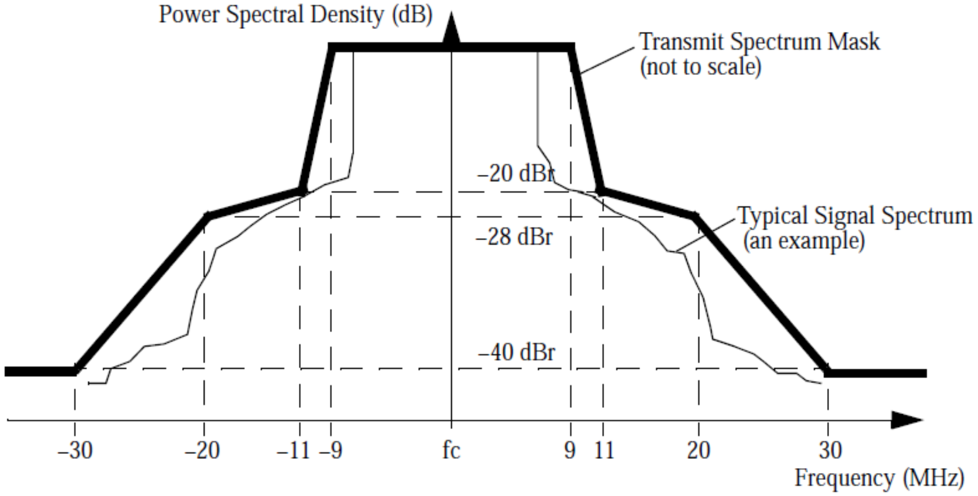
Table I.4—Transmit power level by regulatory domain

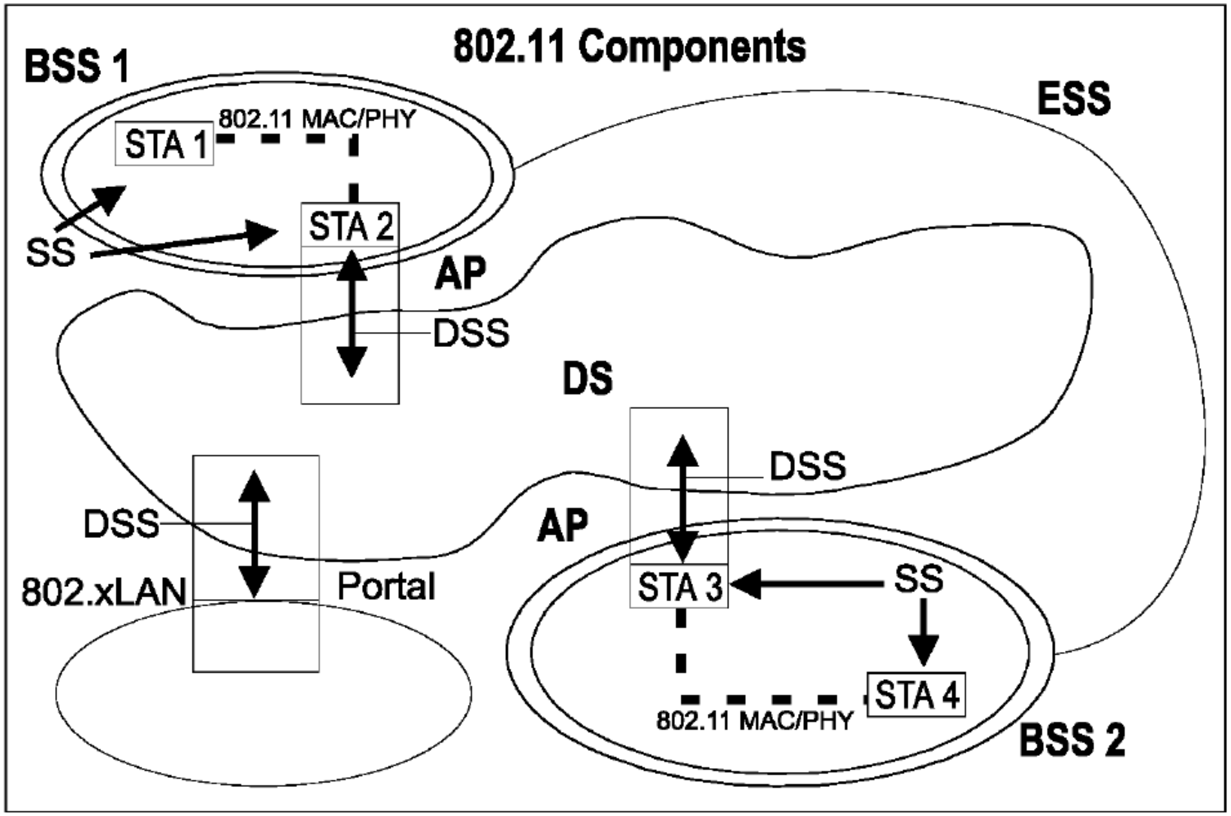
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

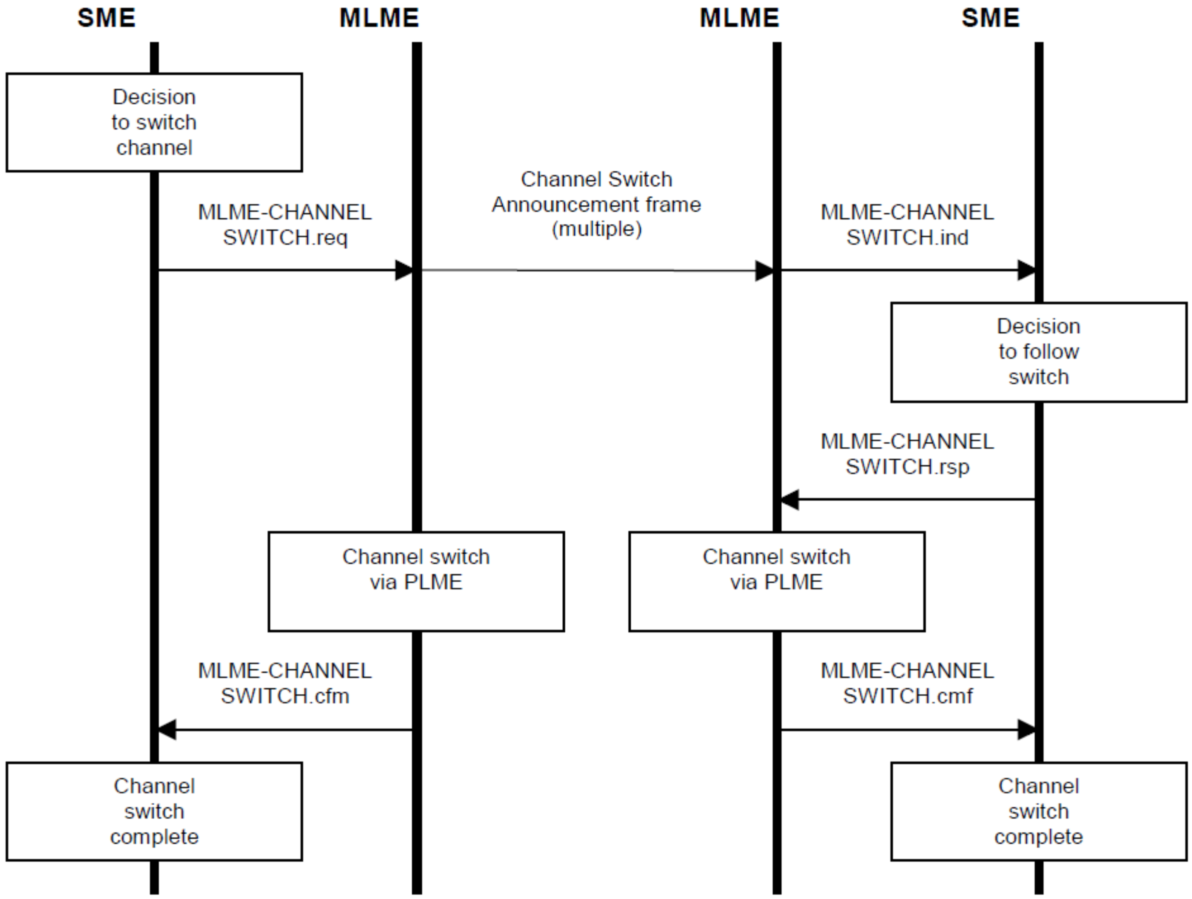
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.5] a first up-converter circuit having a first input coupled to receive the first analog signal and a second input coupled to receive a first modulation signal having a first RF frequency, wherein the first up-converter outputs a first up-converted analog signal comprising a first up-converted frequency range from the first RF frequency minus one-half the first frequency range to the first RF frequency plus one-half the first frequency range;	802.11-2007 discloses “a first up-converter circuit having a first input coupled to receive the first analog signal and a second input coupled to receive a first modulation signal having a first RF frequency, wherein the first up-converter outputs a first up-converted analog signal comprising a first up-converted frequency range from the first RF frequency minus one-half the first frequency range to the first RF frequency plus one-half the first frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other)

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.

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	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use

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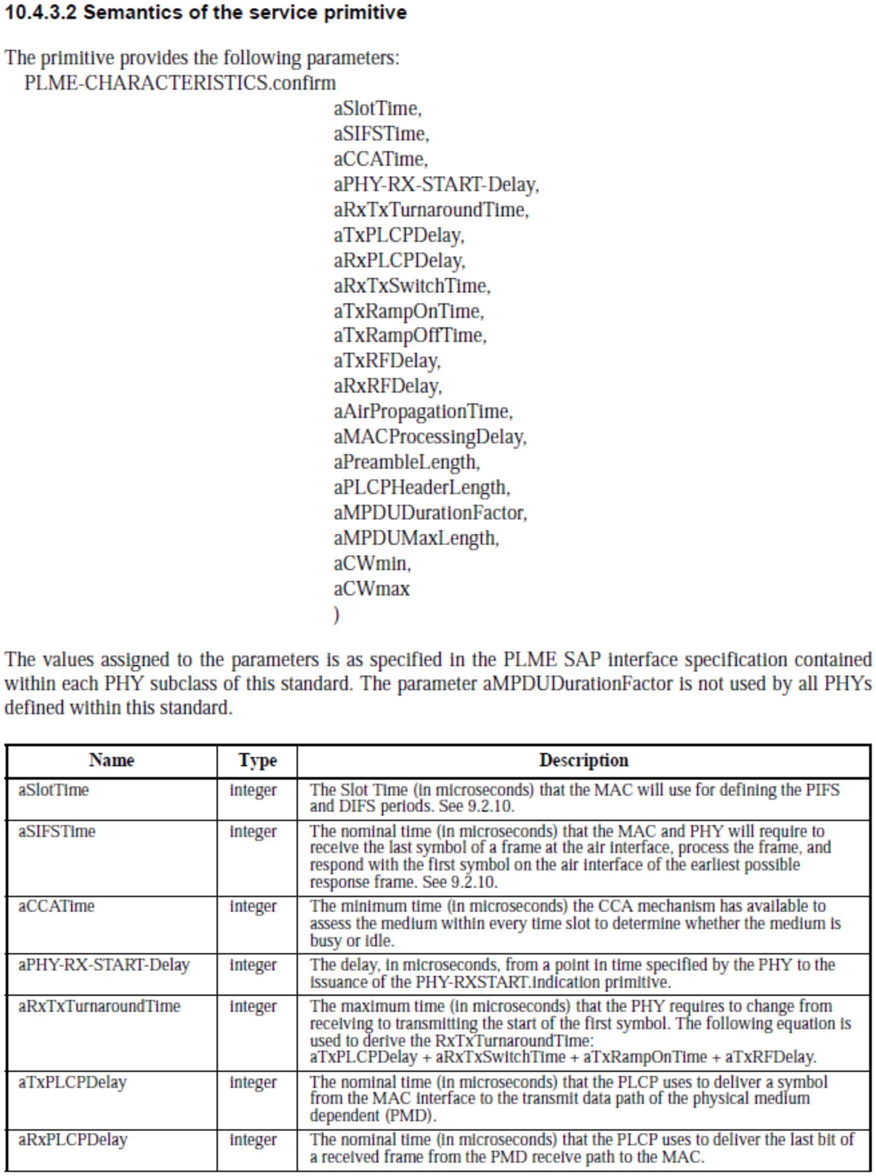
	transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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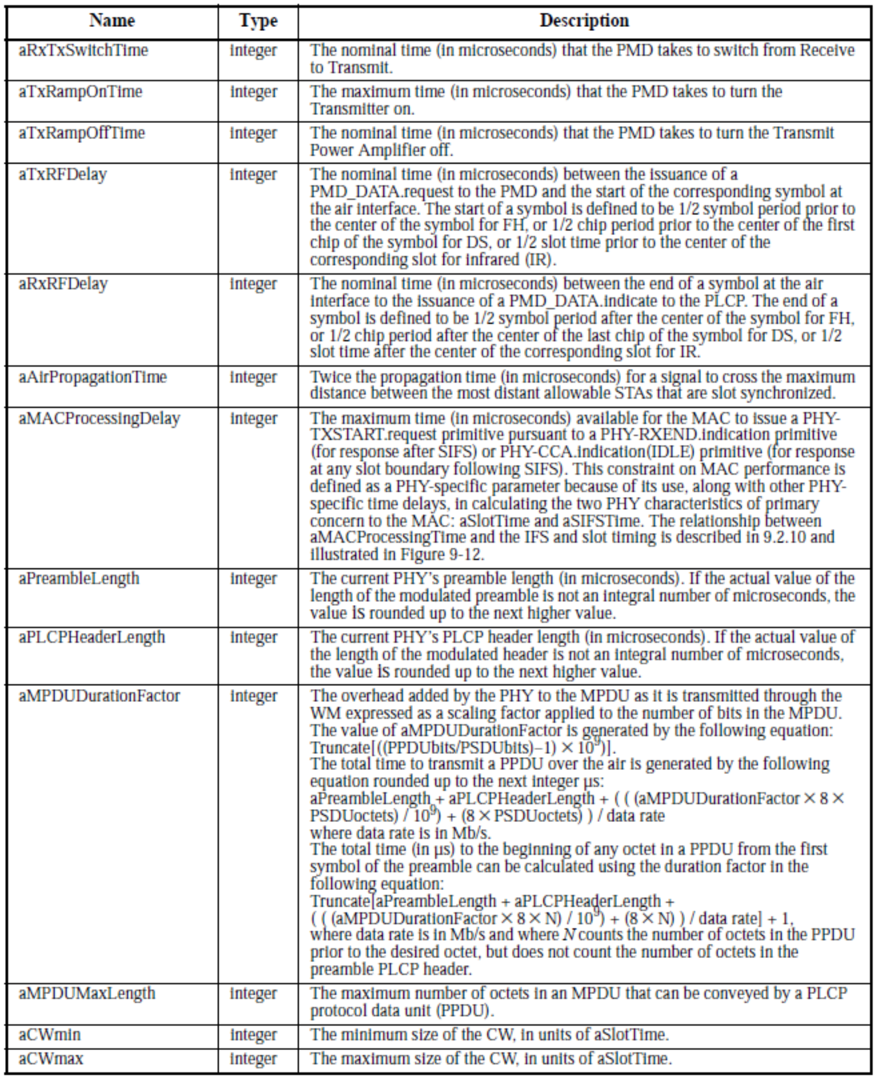

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)−1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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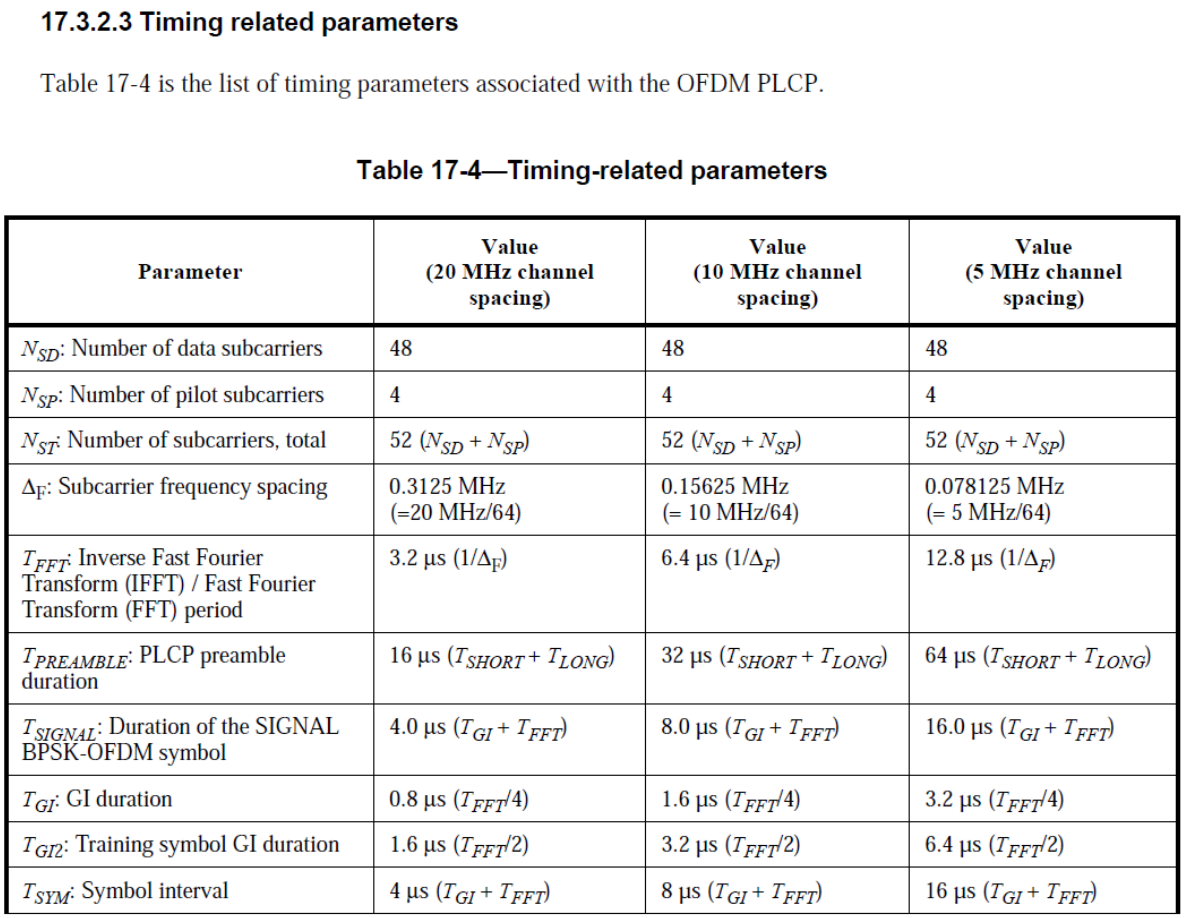
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

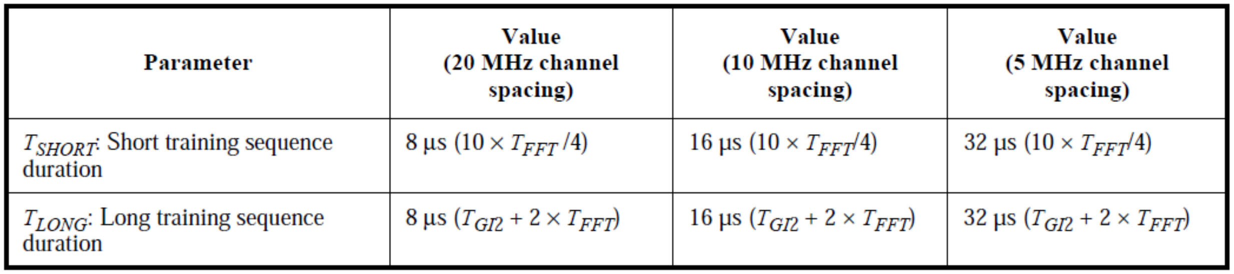
Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

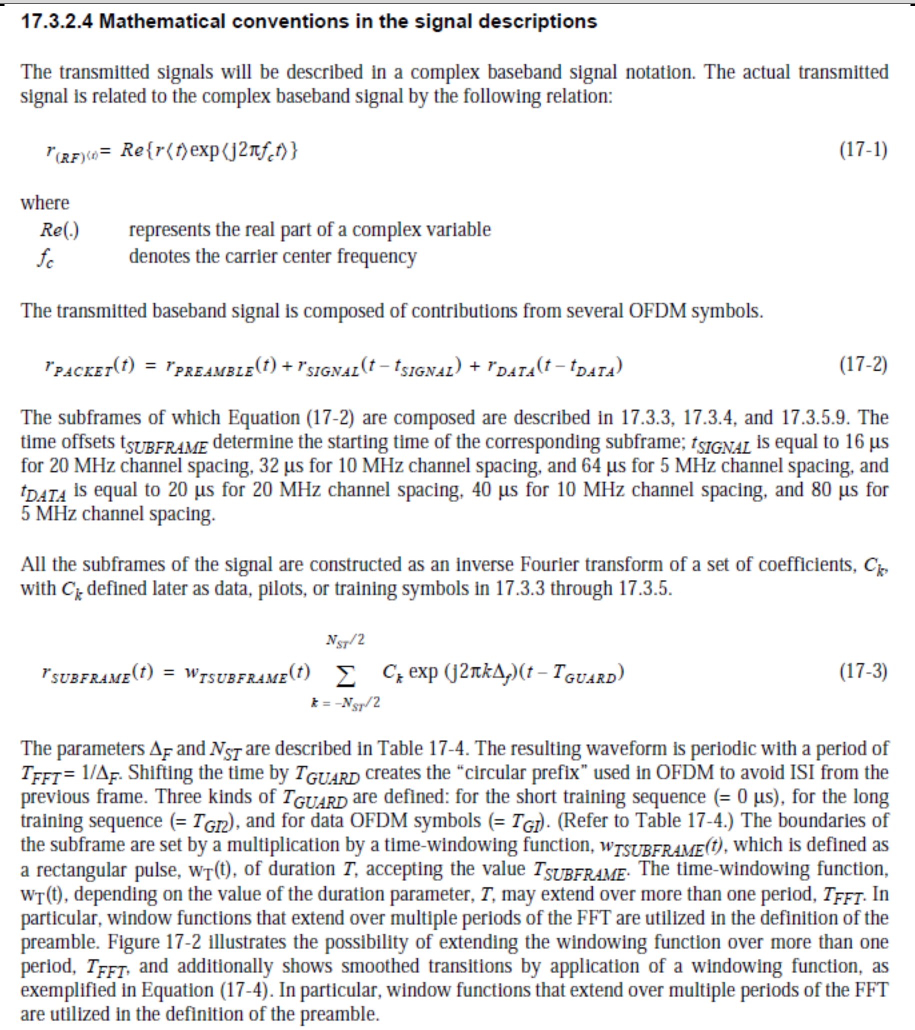
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	**Value (20 MHz channel spacing)**	**Value (10 MHz channel spacing)**	**Value (5 MHz channel spacing)**
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

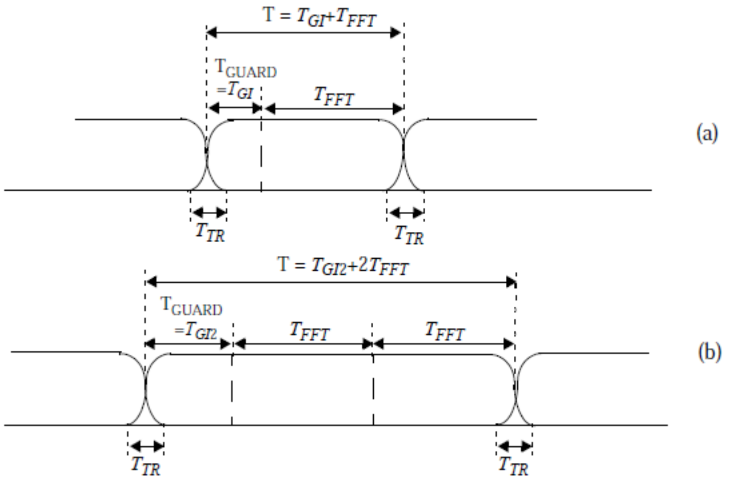
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

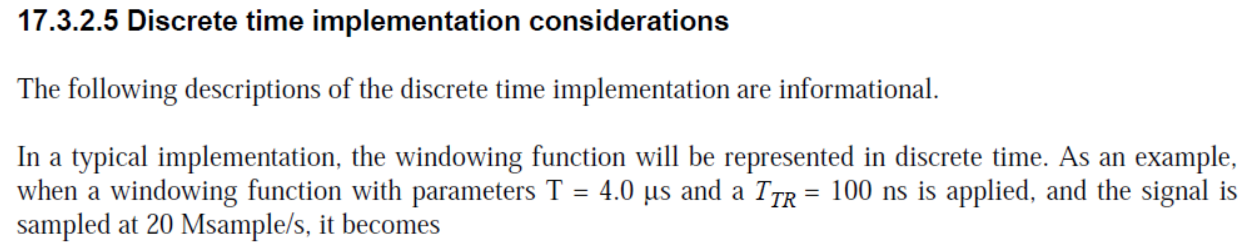
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

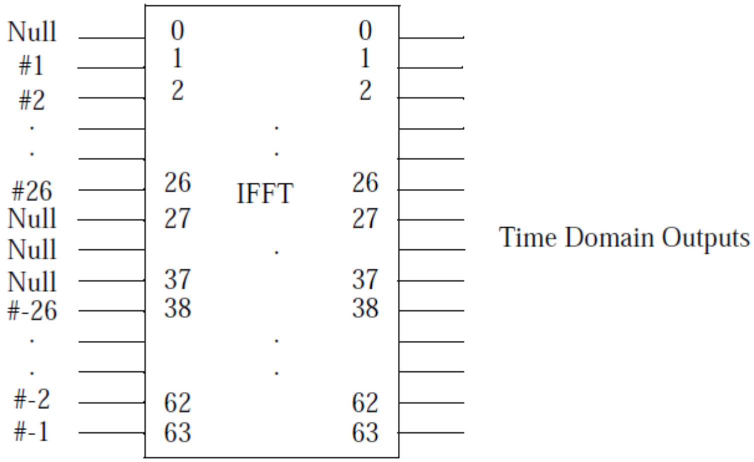
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

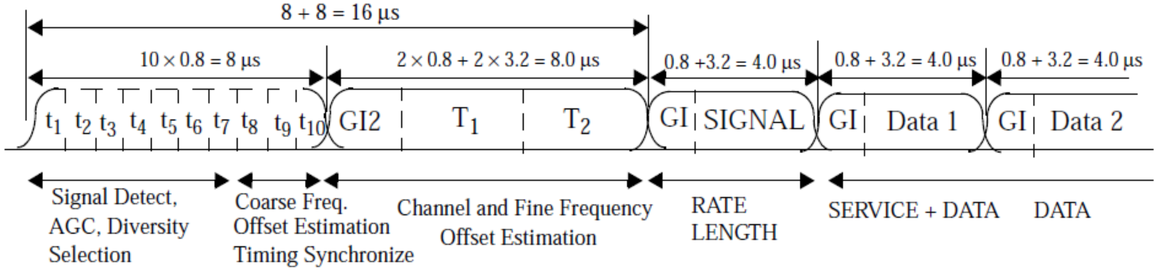
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

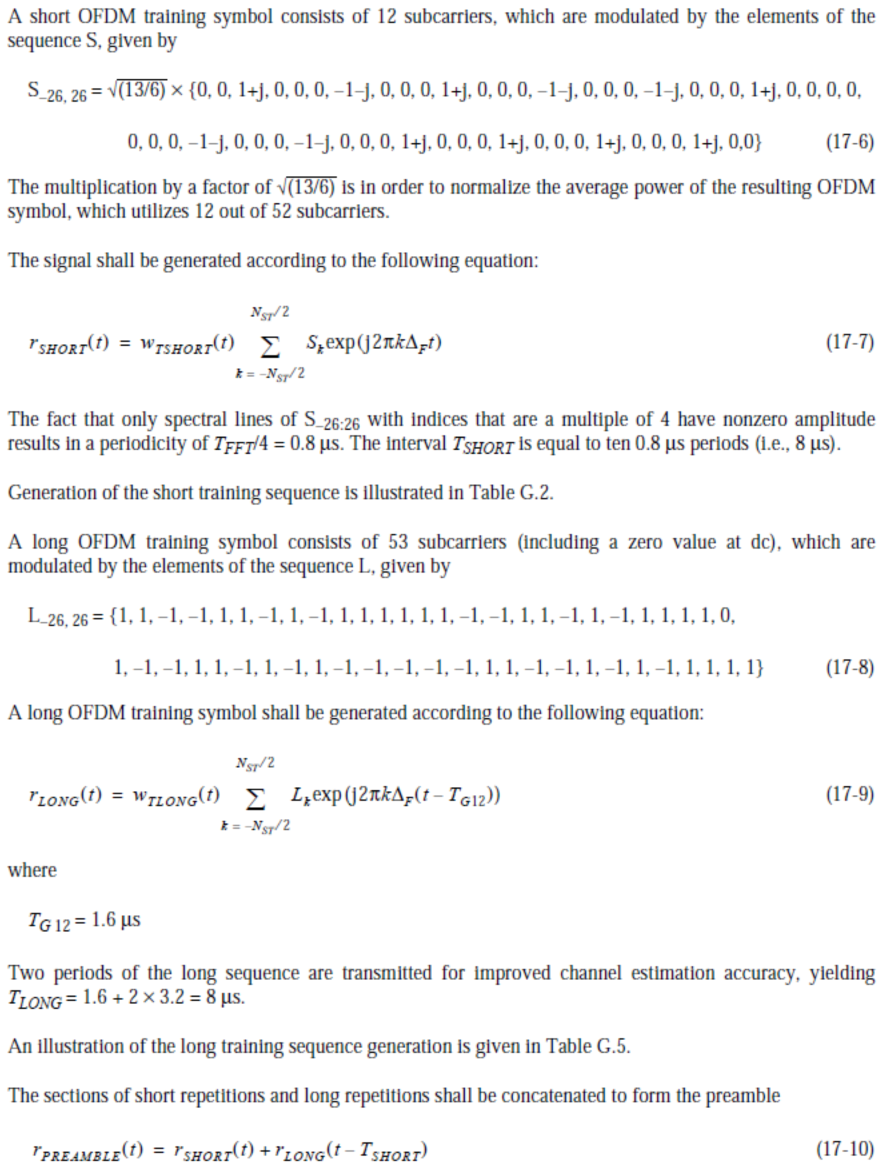
The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

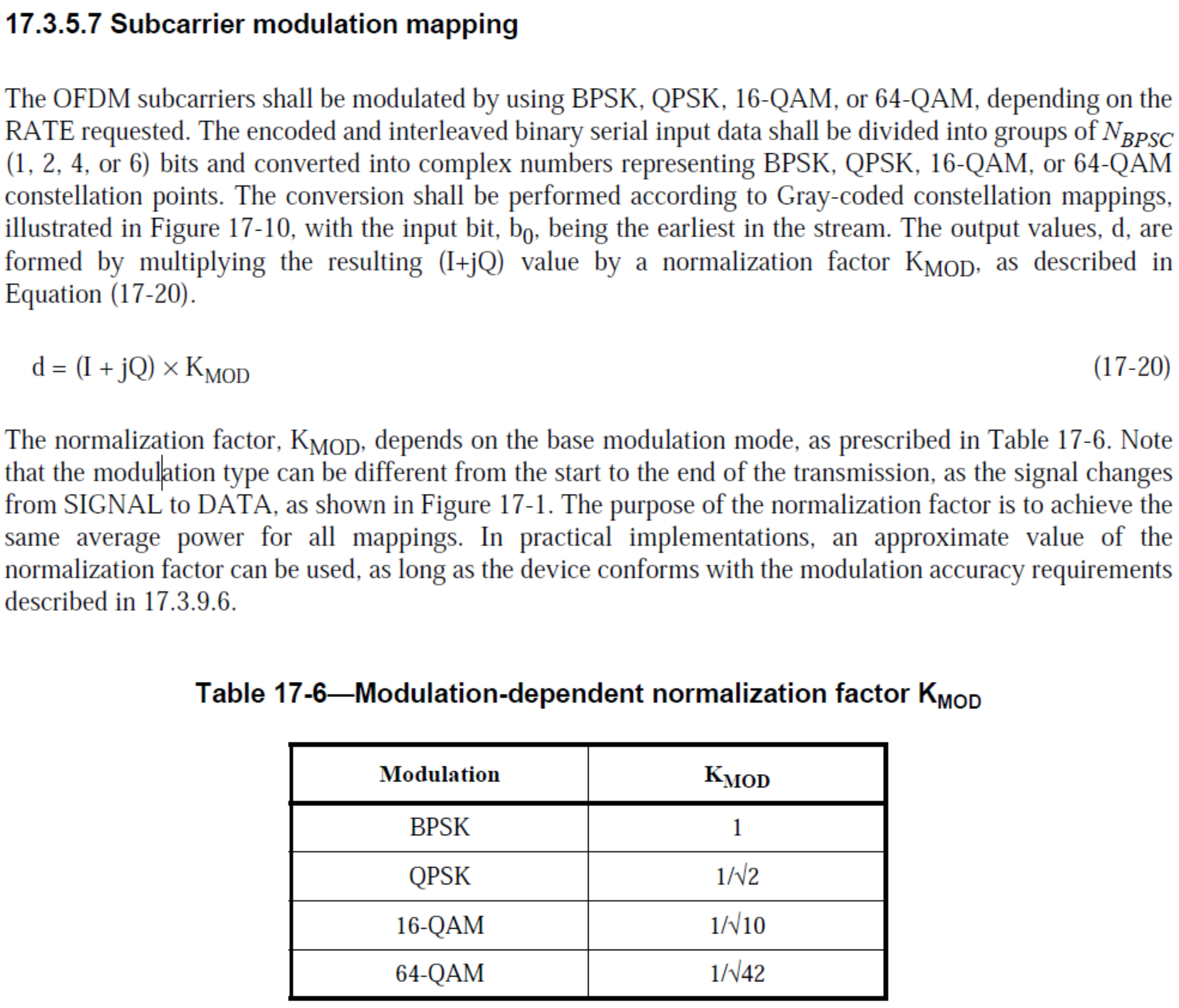
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \tag{17-25}$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

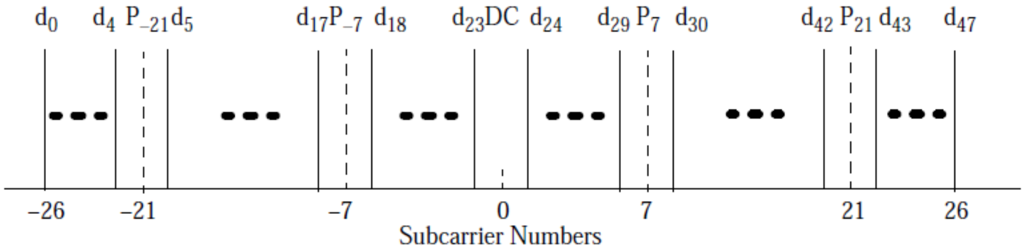


Figure 17-11—Subcarrier frequency allocation

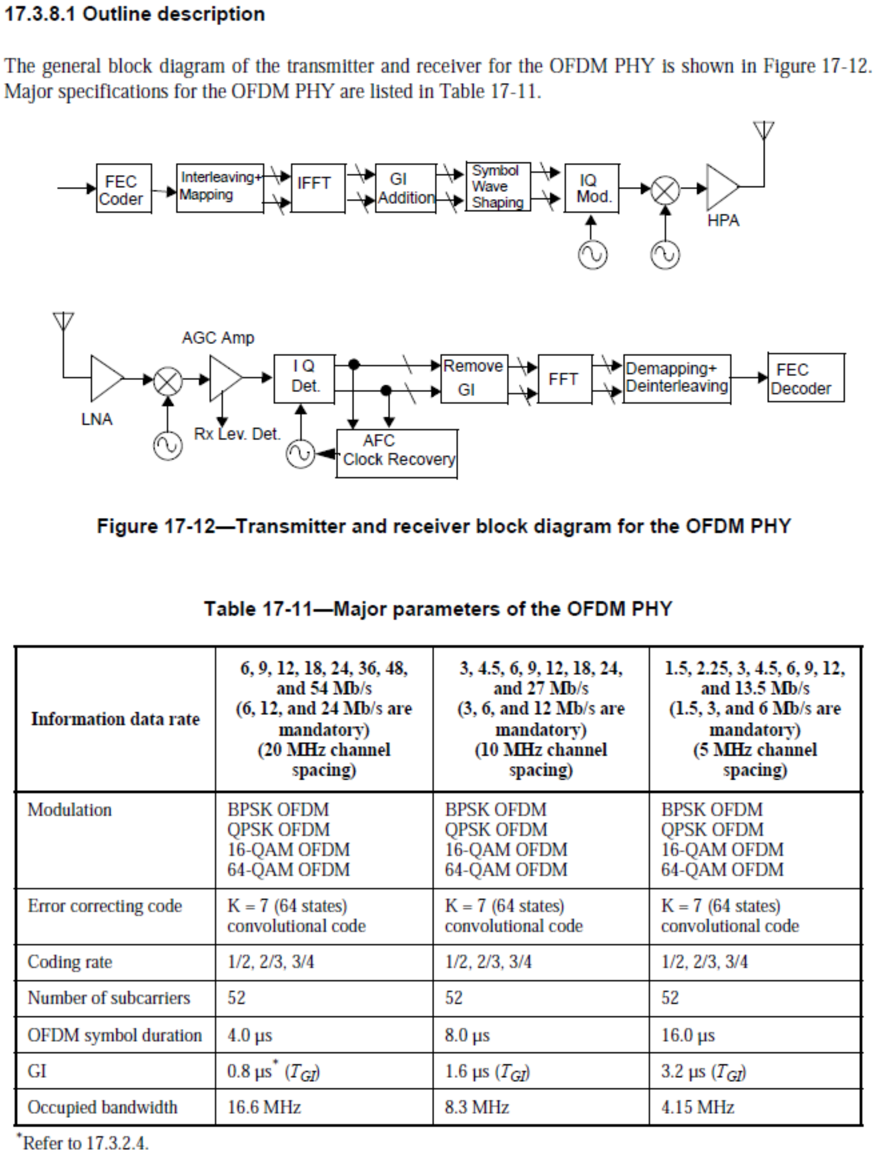
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \tag{17-26}$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

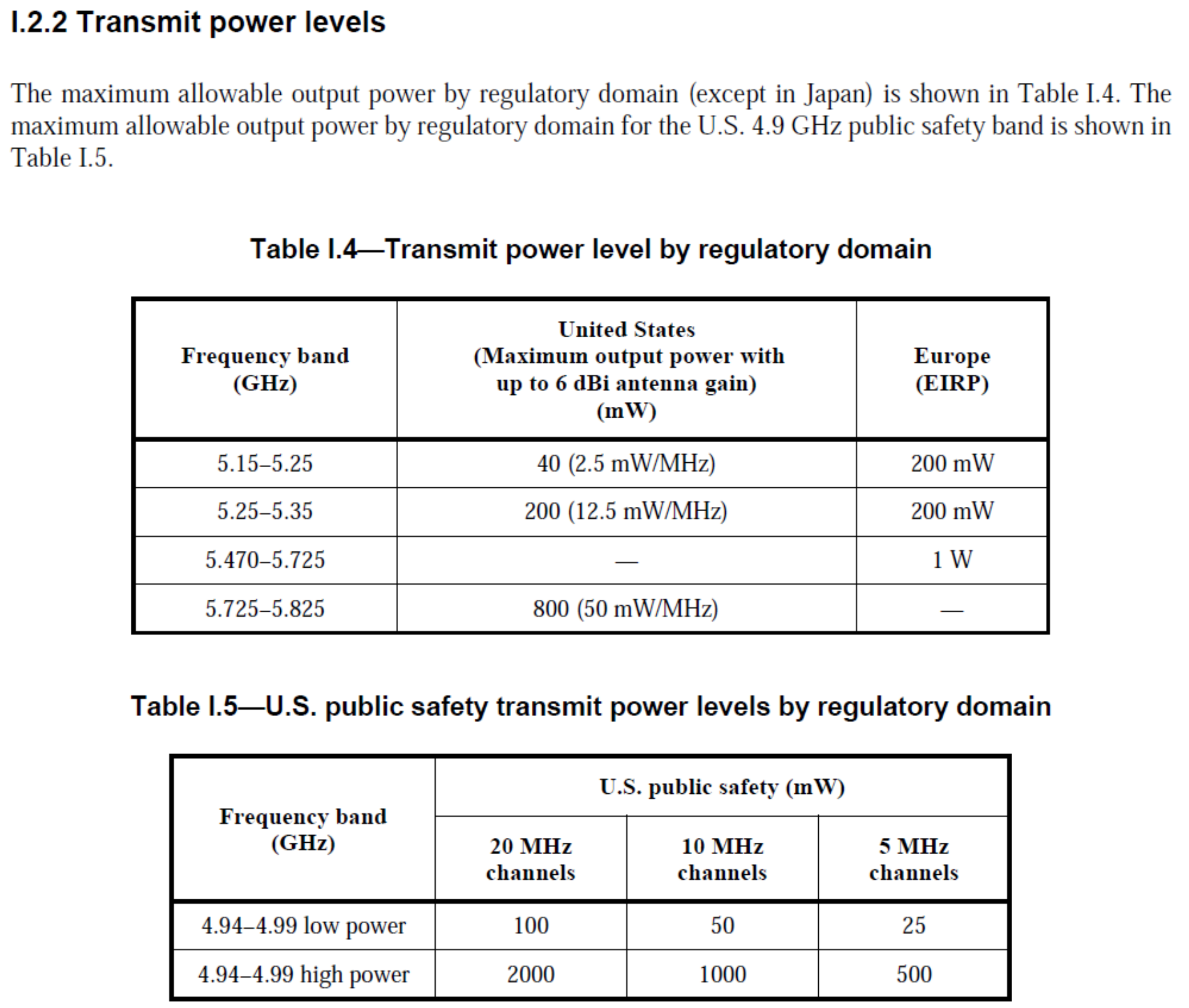
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

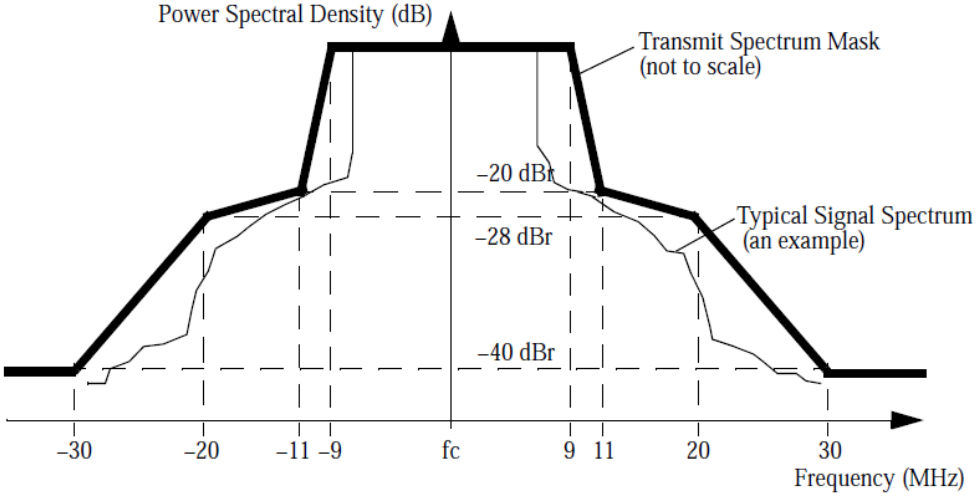
Table I.4—Transmit power level by regulatory domain

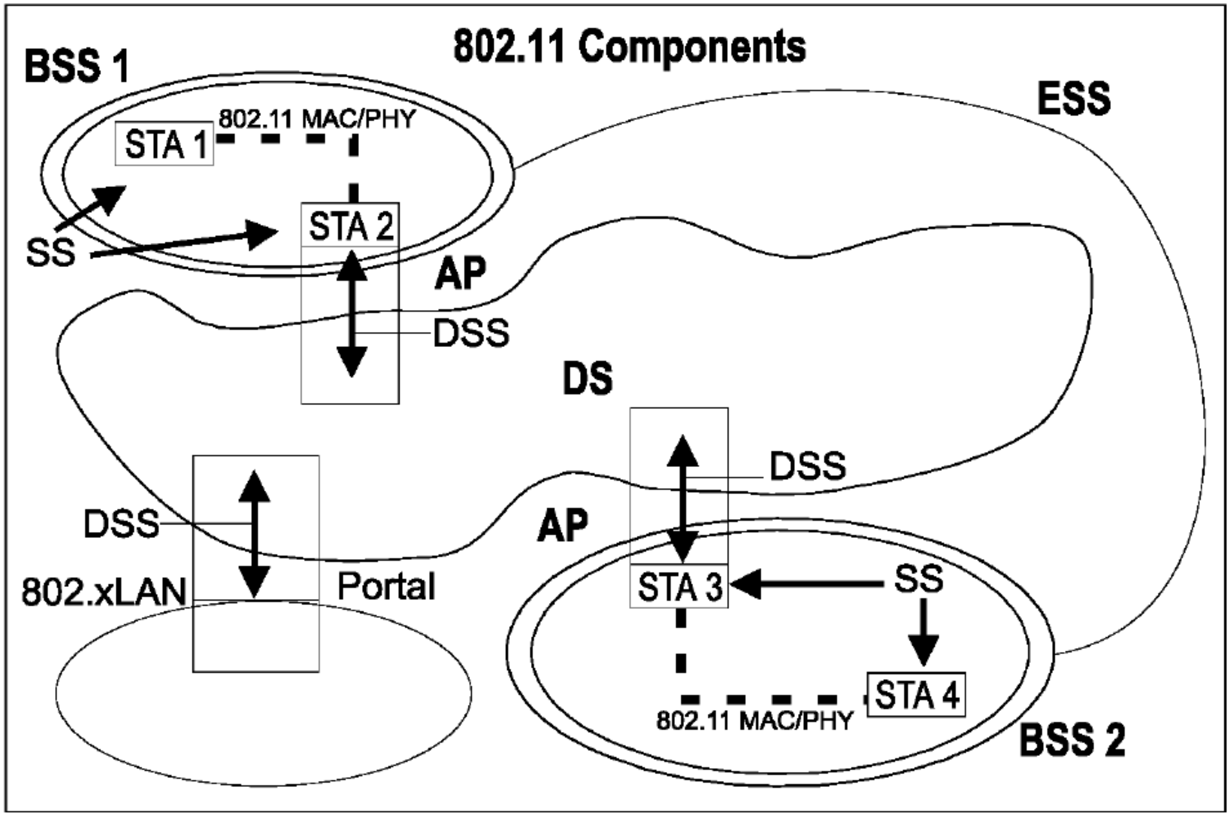
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

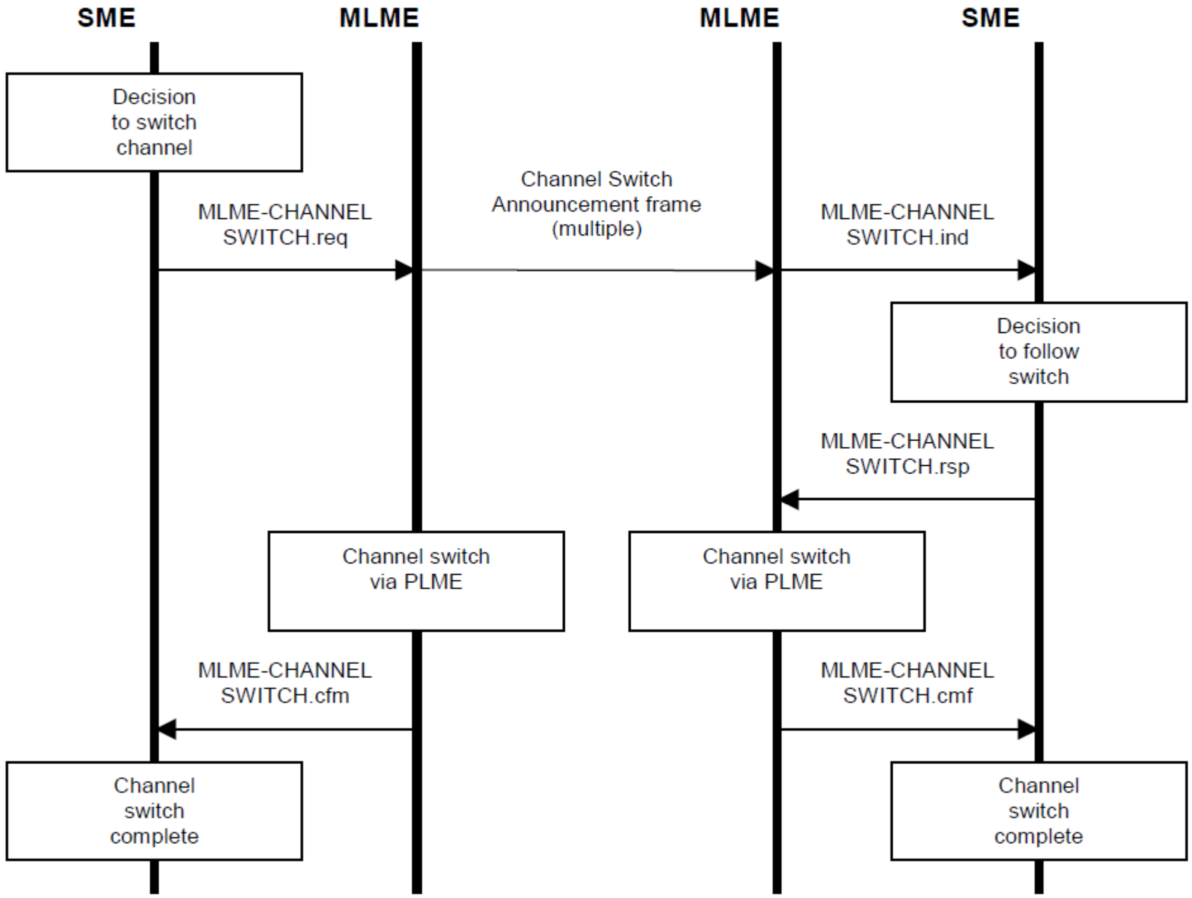
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.6] a second up-converter circuit having a first input coupled to receive the second analog signal and a second input coupled to receive a second modulation signal having a second RF frequency, wherein the second up-converter outputs a second up-converted analog signal comprising a second up-converted frequency range from the second RF frequency minus one-half the second frequency range to the second RF frequency plus one-half the second frequency range, and wherein frequency difference between the first RF frequency and the second RF frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range; and	802.11-2007 discloses “a second up-converter circuit having a first input coupled to receive the second analog signal and a second input coupled to receive a second modulation signal having a second RF frequency, wherein the second up-converter outputs a second up-converted analog signal comprising a second up-converted frequency range from the second RF frequency minus one-half the second frequency range to the second RF frequency plus one-half the second frequency range, and wherein frequency difference between the first RF frequency and the second RF frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2

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	5.2.3 Distribution system (DS) concepts PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

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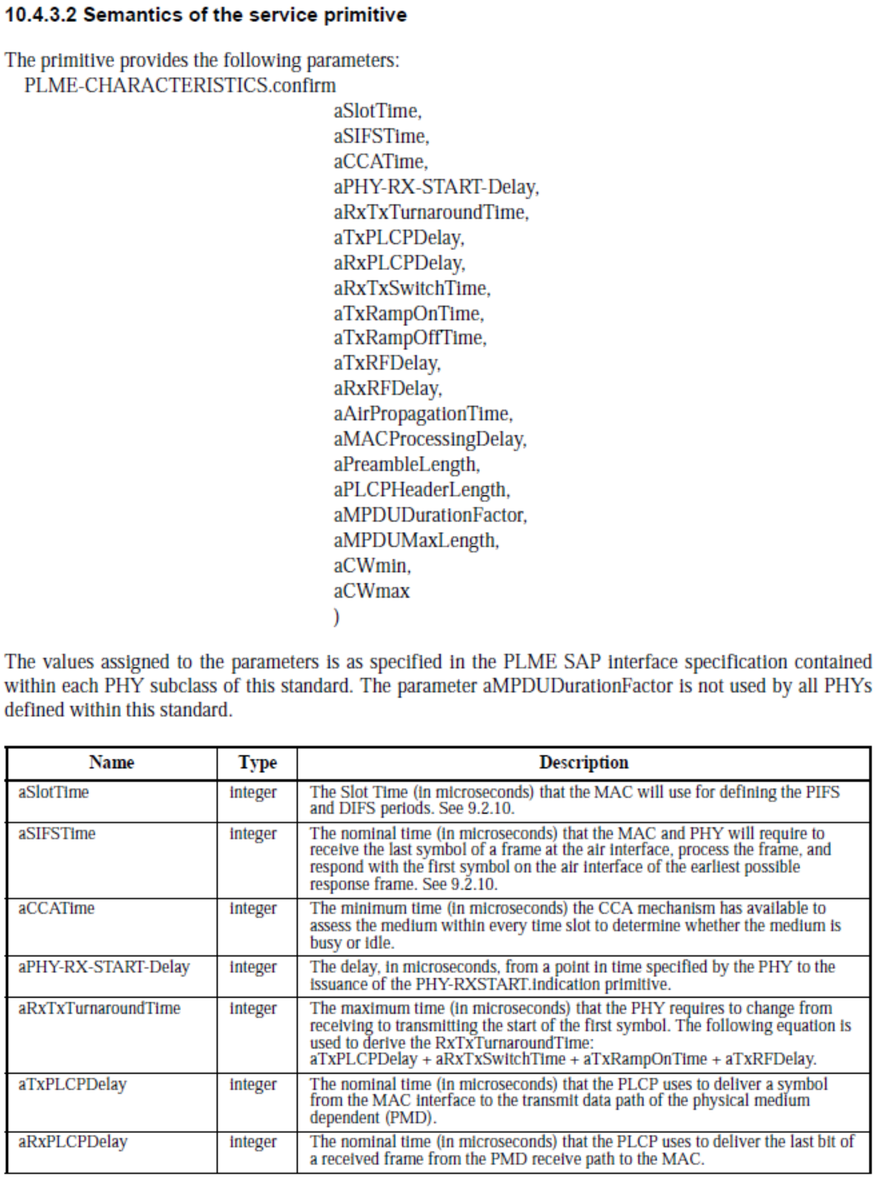
	See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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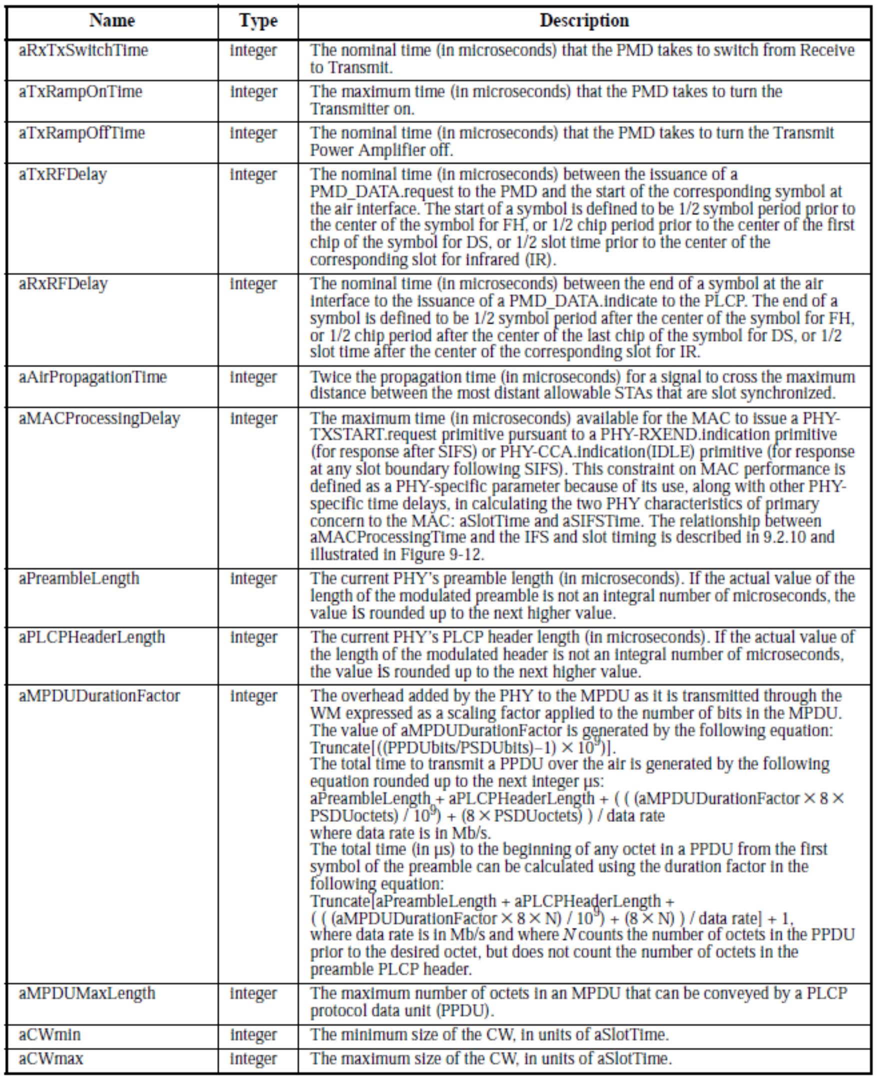

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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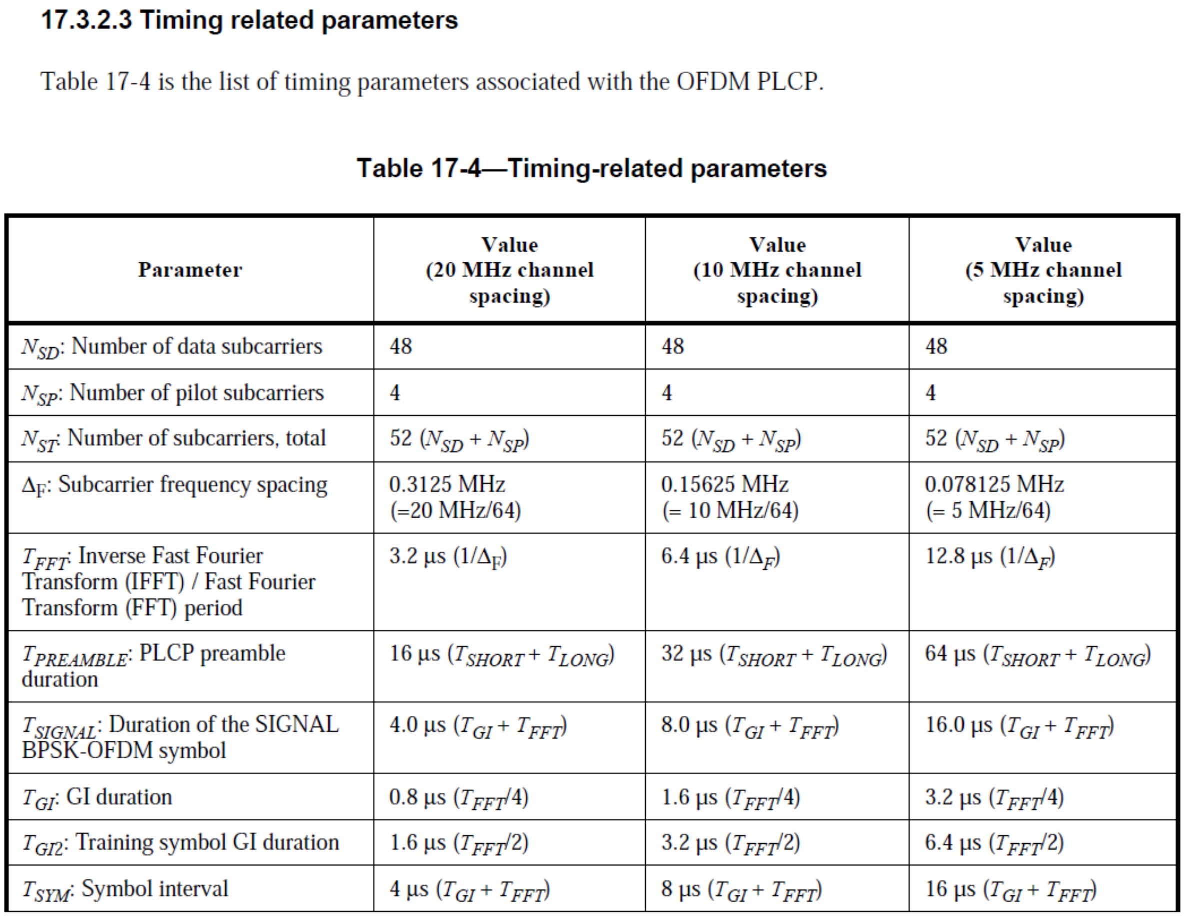
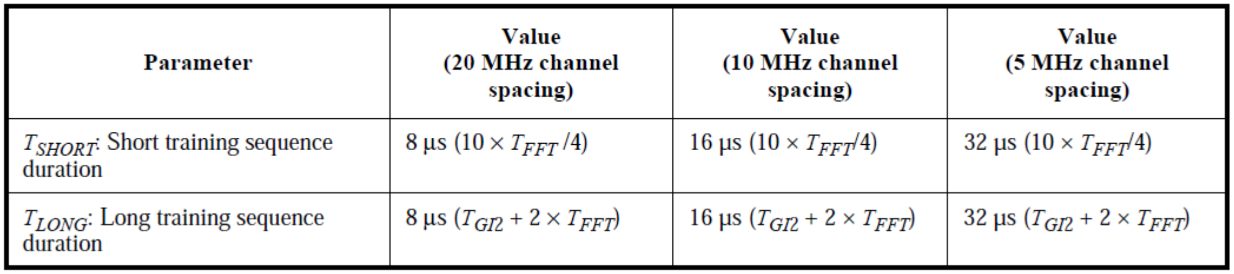
	

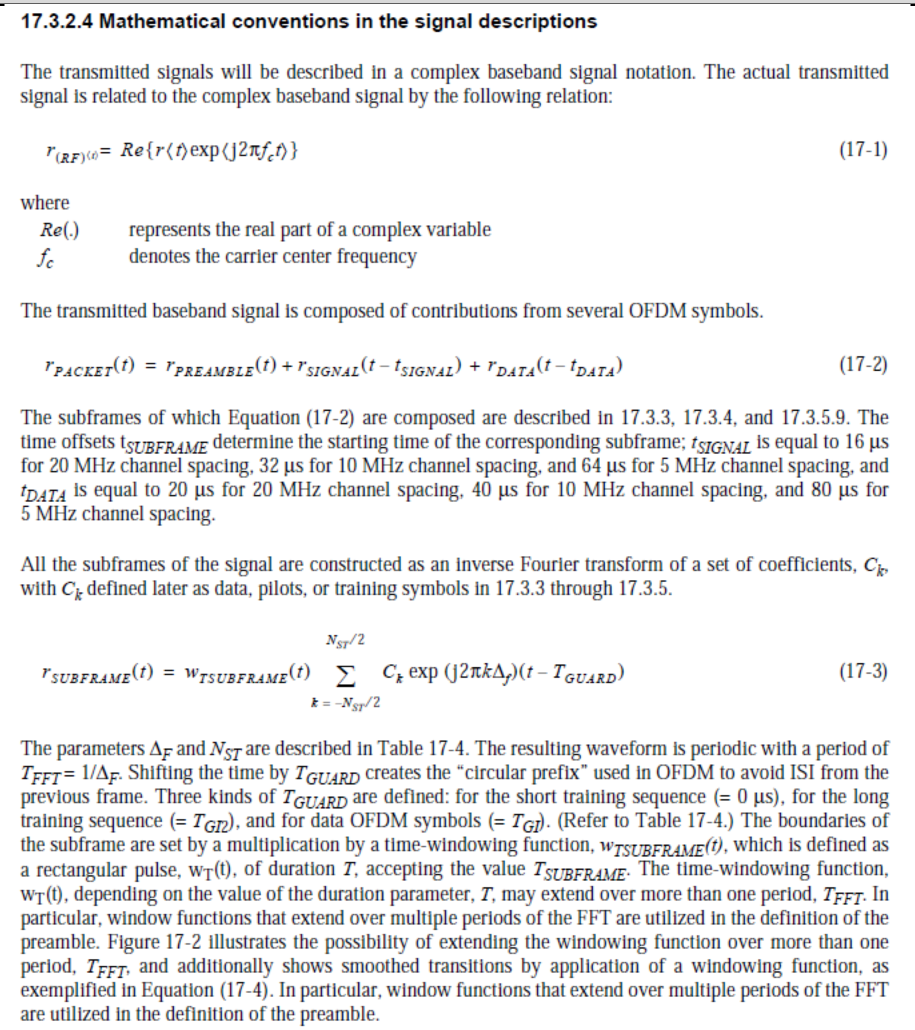
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)(t)} = Re\{r(t)\exp(j2\pi f_c t)\} \tag{17-1}$$

where

$Re(.)$	represents the real part of a complex variable
f_c	denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \tag{17-2}$$

The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \tag{17-3}$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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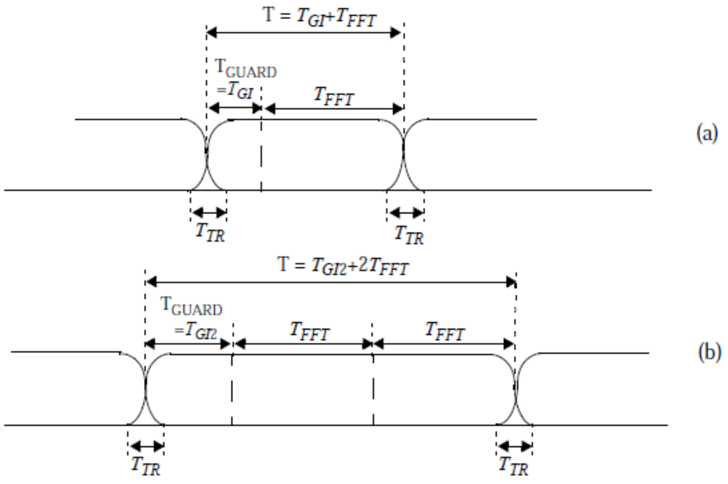
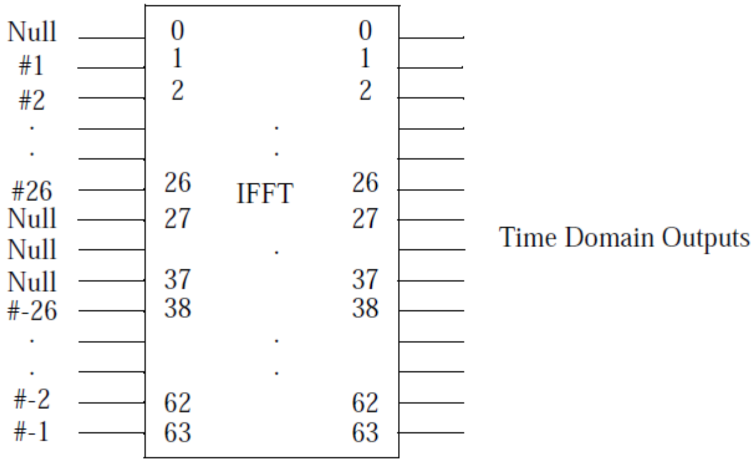
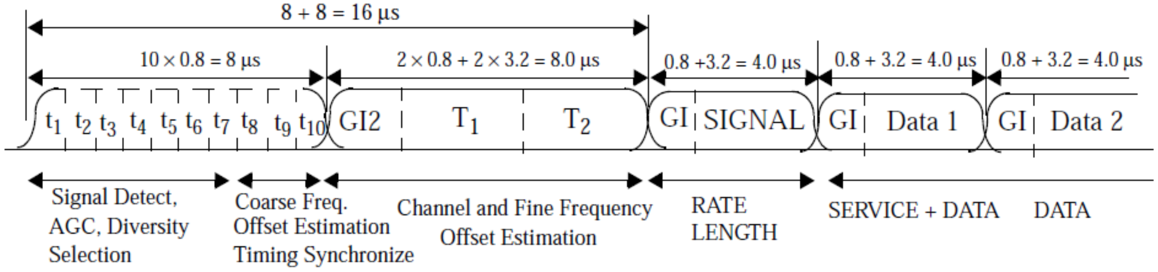
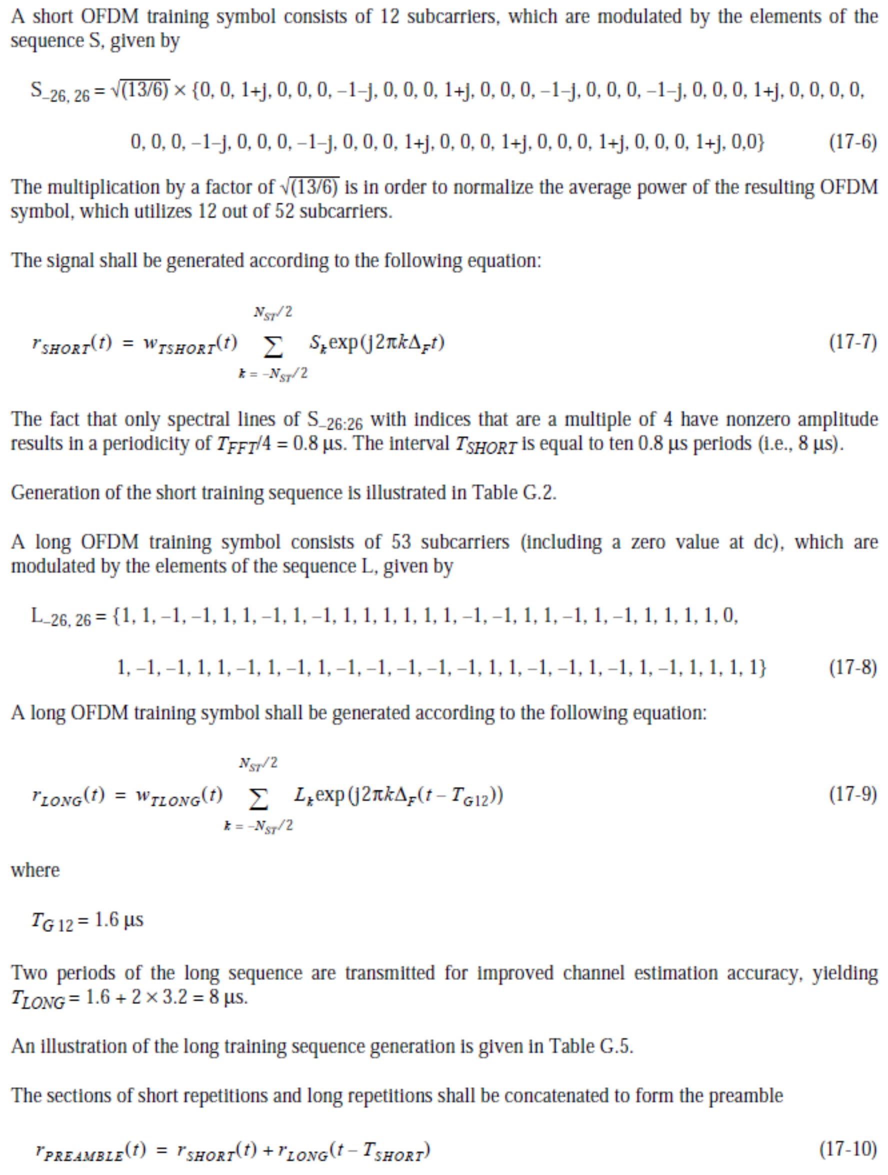
	$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{ \begin{matrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{matrix} \right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F(t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

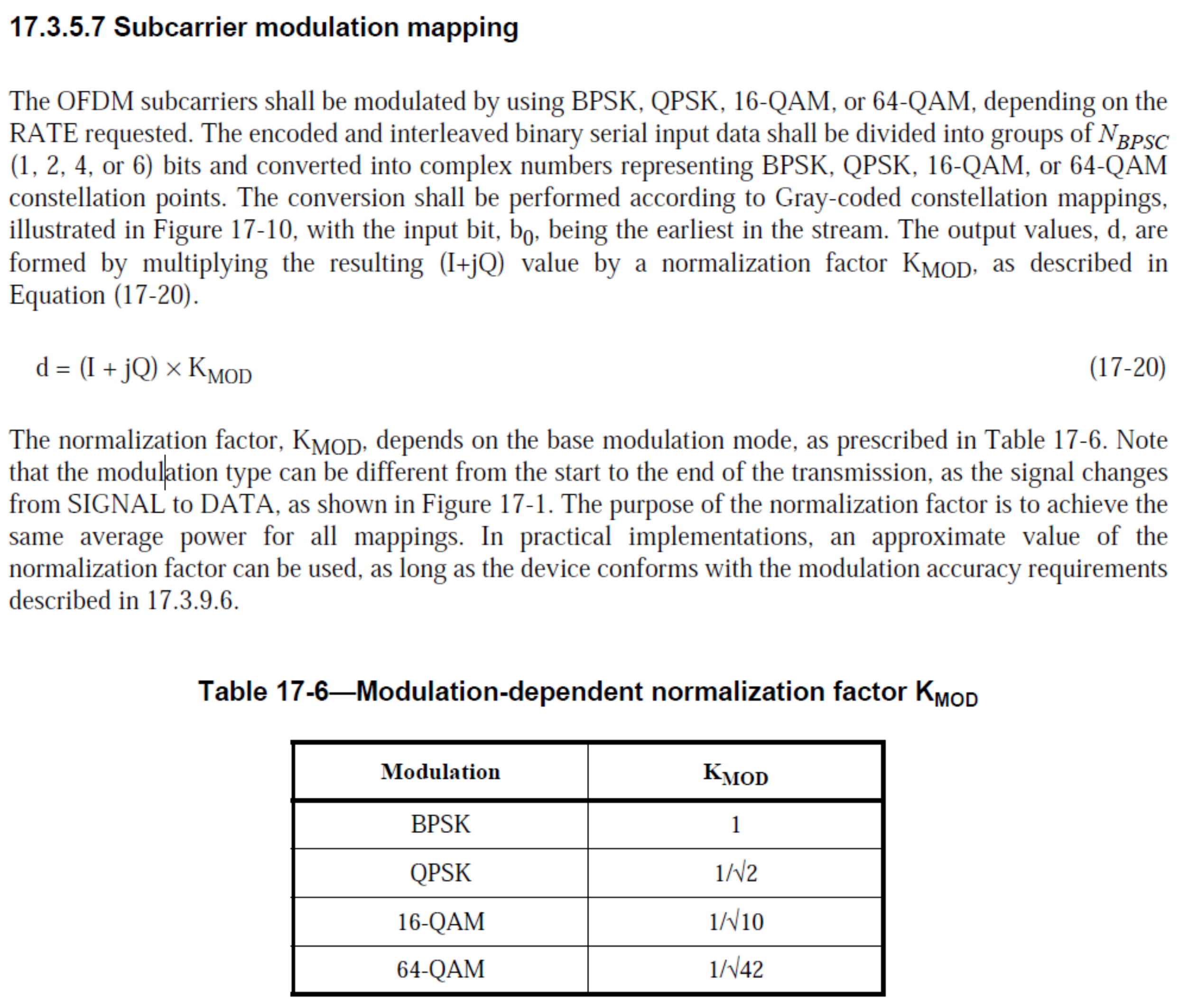
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

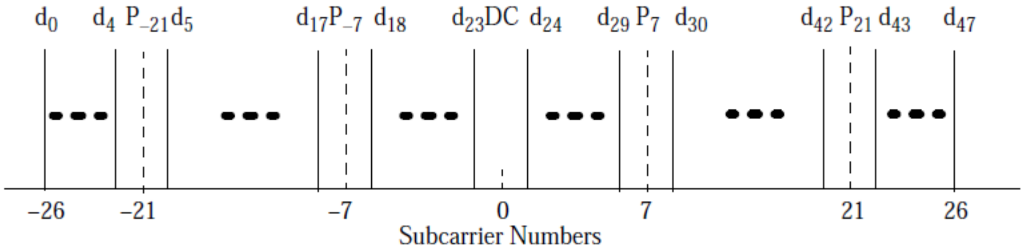


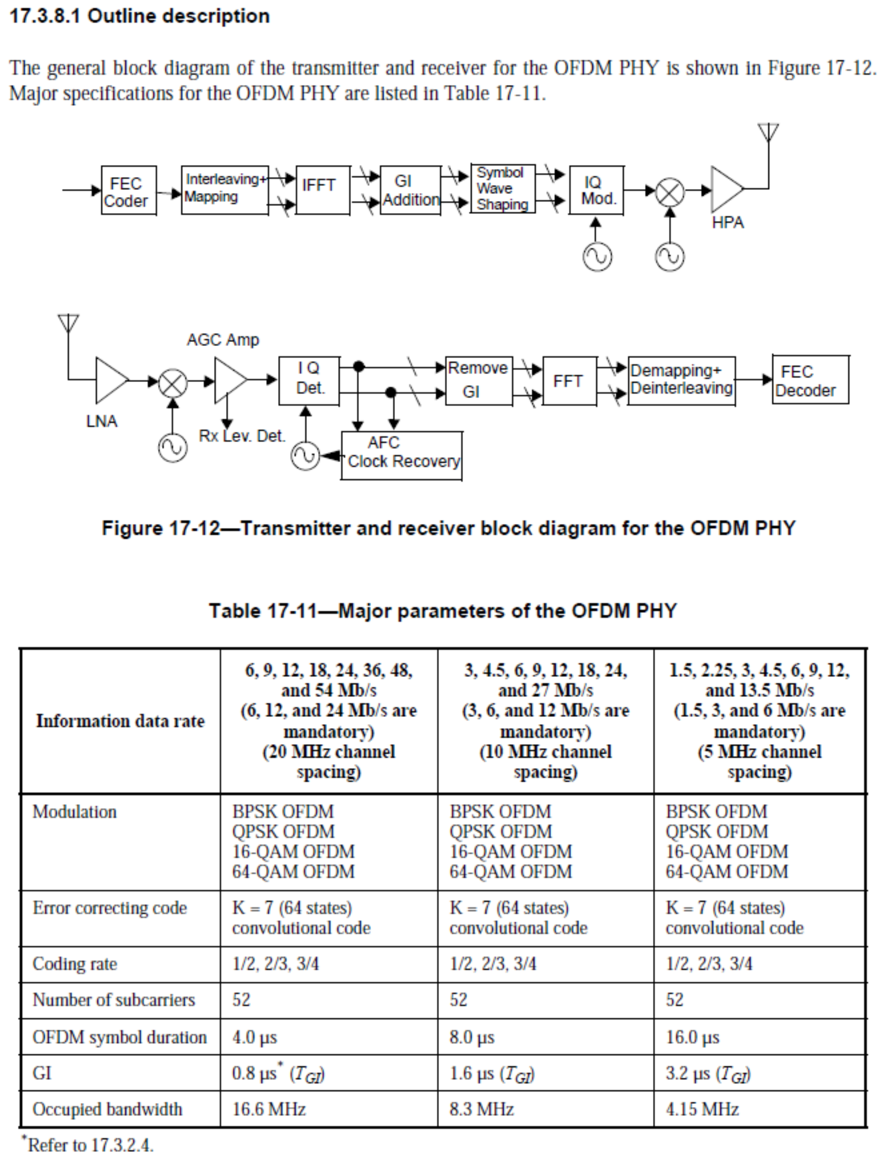
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

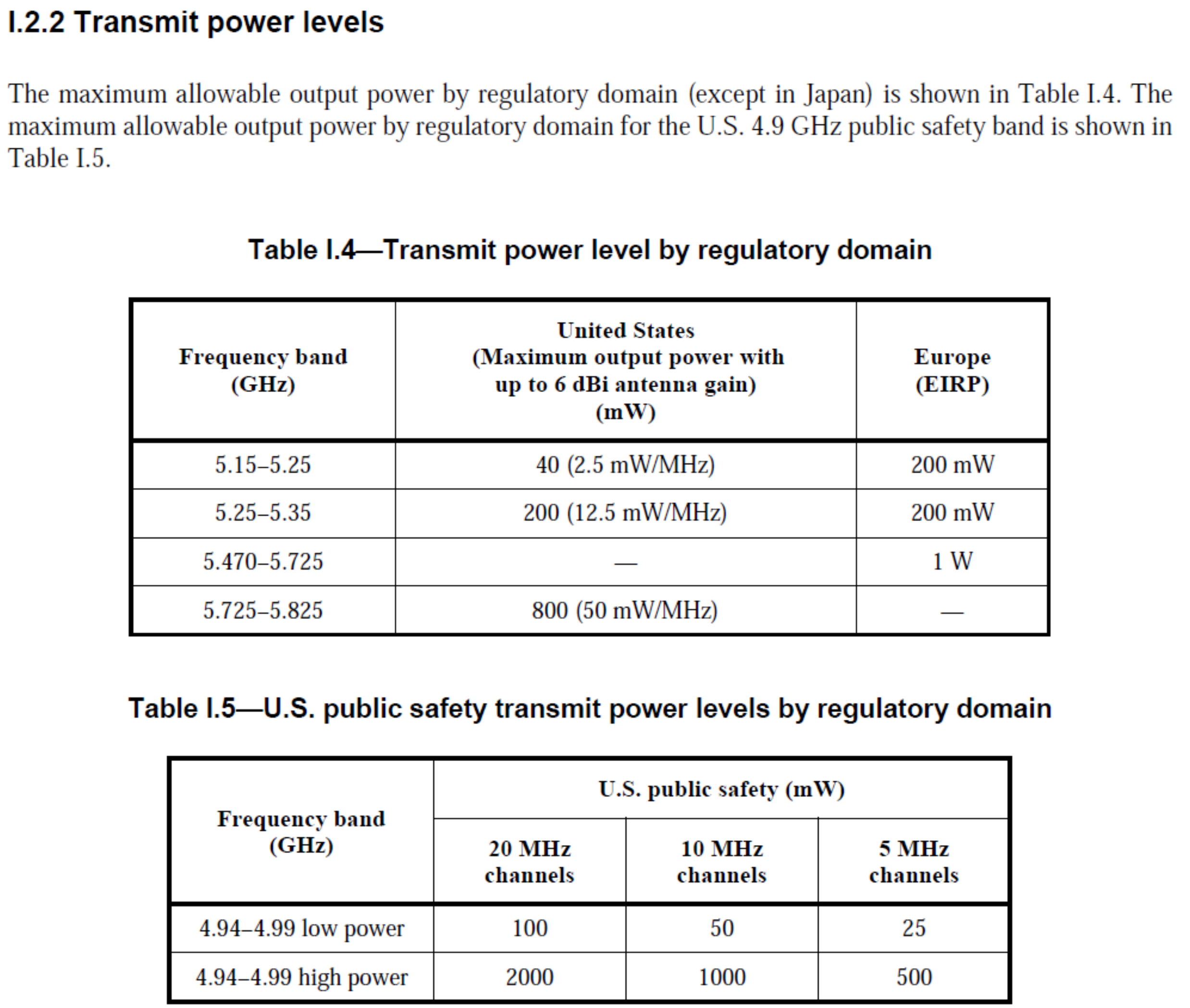
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

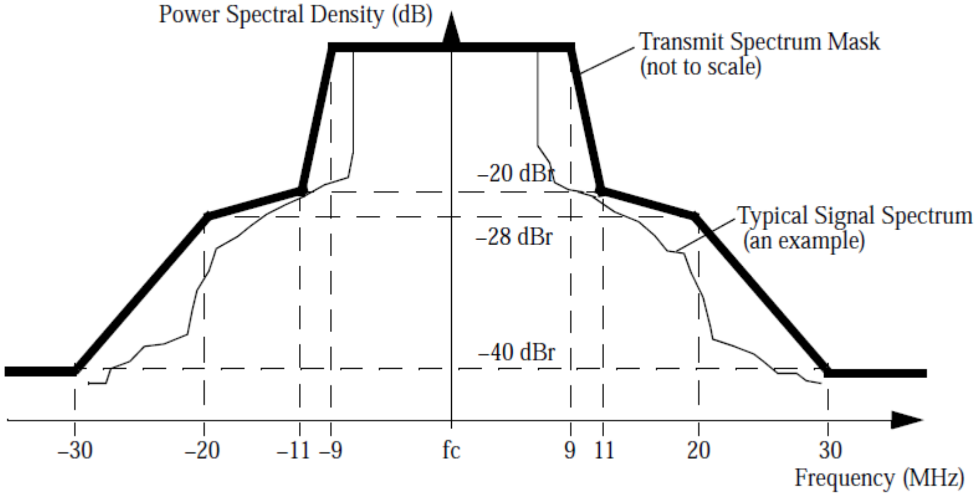
Table I.4—Transmit power level by regulatory domain

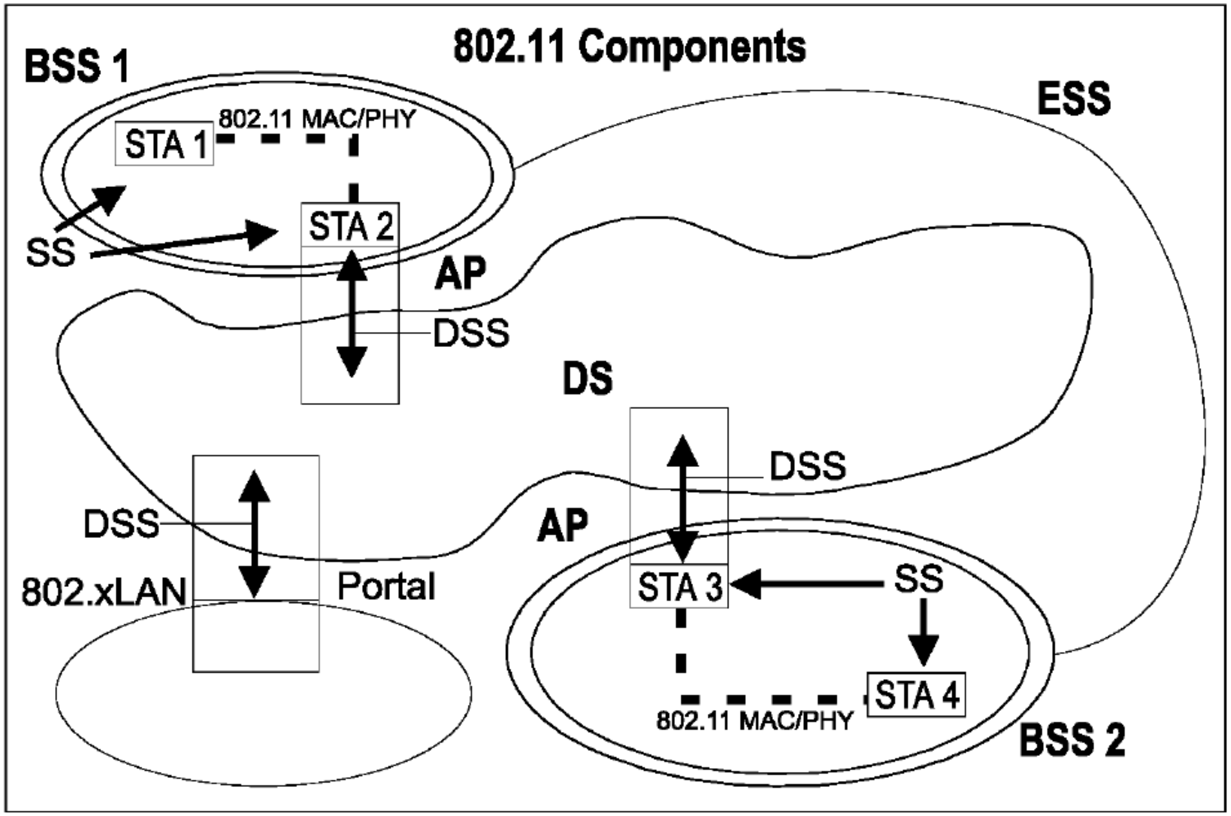
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

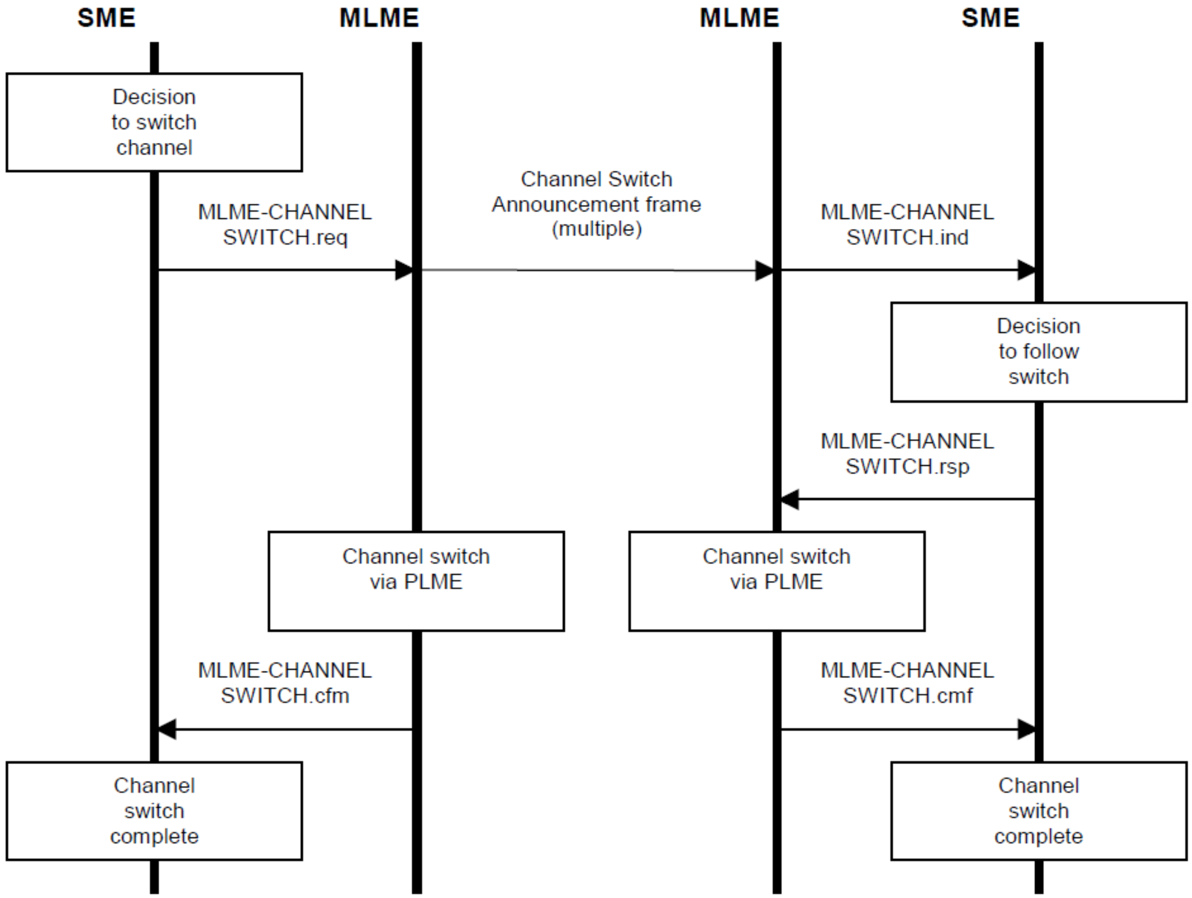
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.7] a power amplifier coupled to receive the first and second up-converted analog signals, wherein the bandwidth of the power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range.	802.11-2007 discloses "a power amplifier coupled to receive the first and second up-converted analog signals, wherein the bandwidth of the power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

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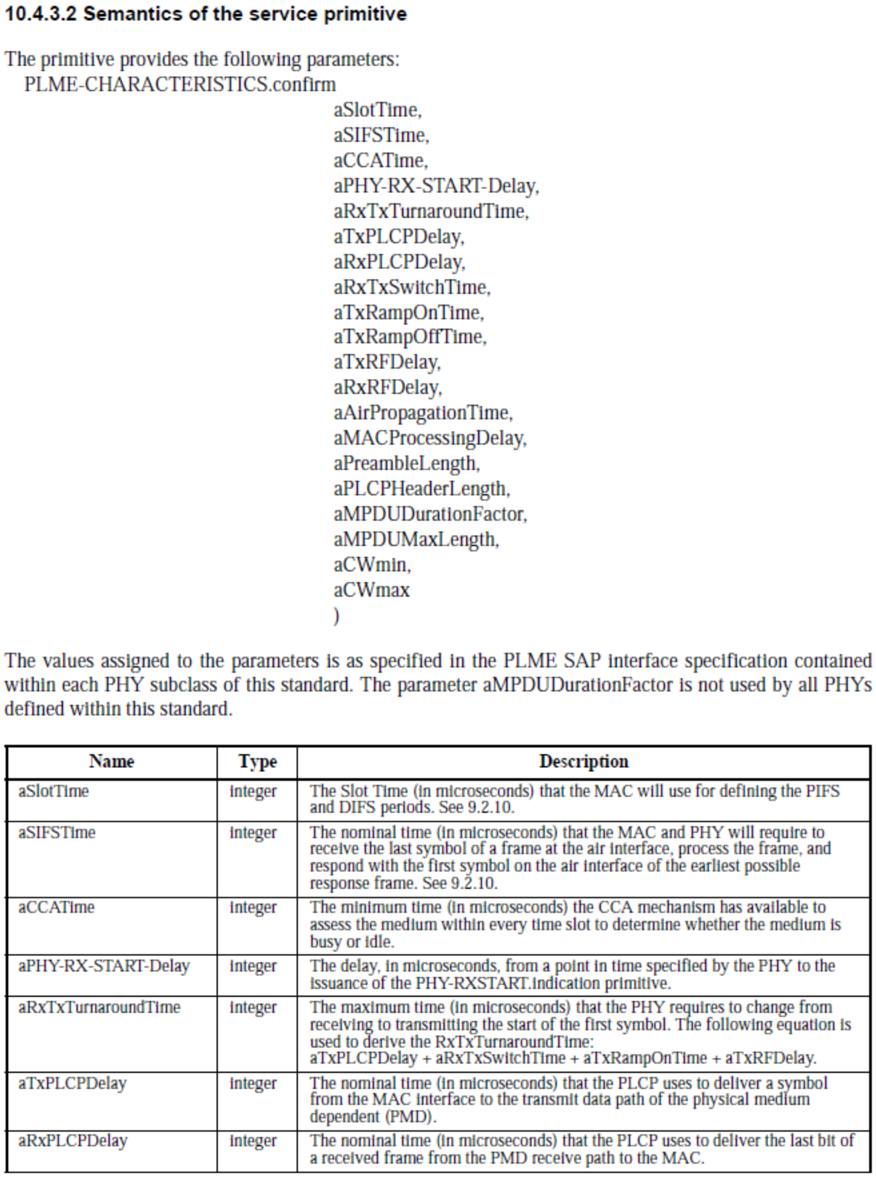
	to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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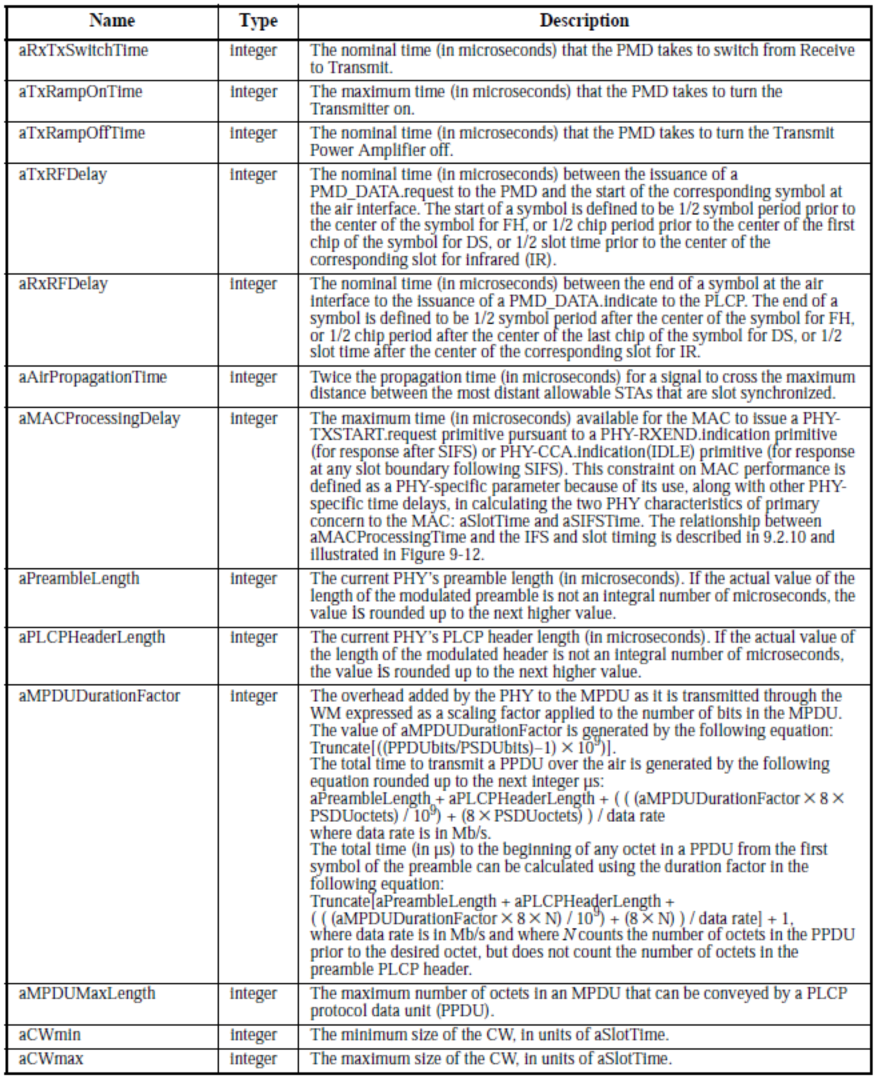

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

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	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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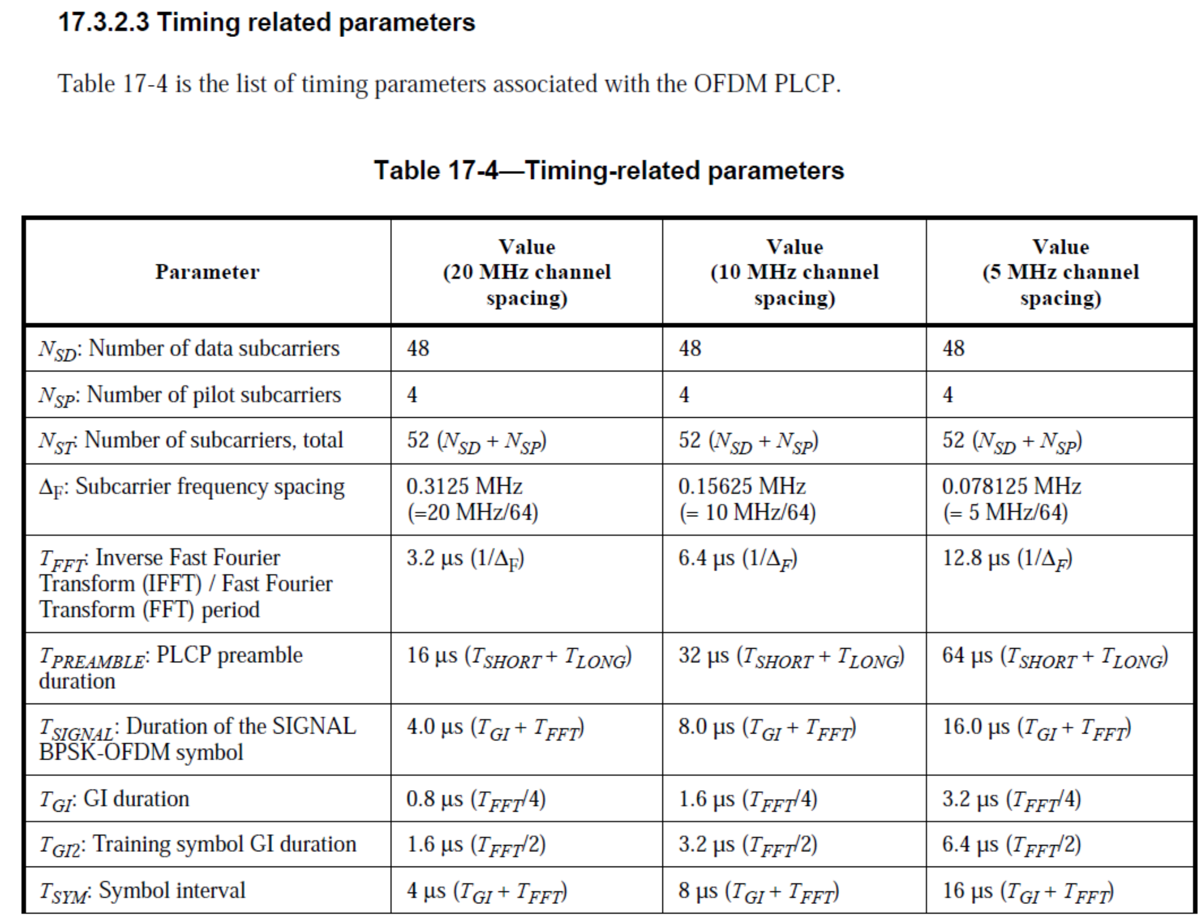
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz (=20 MHz/64)</td><td>0.15625 MHz (= 10 MHz/64)</td><td>0.078125 MHz (= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 µs ($1/\Delta_F$)</td><td>6.4 µs ($1/\Delta_F$)</td><td>12.8 µs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 µs ($T_{SHORT} + T_{LONG}$)</td><td>32 µs ($T_{SHORT} + T_{LONG}$)</td><td>64 µs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 µs ($T_{GI} + T_{FFT}$)</td><td>8.0 µs ($T_{GI} + T_{FFT}$)</td><td>16.0 µs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 µs ($T_{FFT}/4$)</td><td>1.6 µs ($T_{FFT}/4$)</td><td>3.2 µs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 µs ($T_{FFT}/2$)</td><td>3.2 µs ($T_{FFT}/2$)</td><td>6.4 µs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 µs ($T_{GI} + T_{FFT}$)</td><td>8 µs ($T_{GI} + T_{FFT}$)</td><td>16 µs ($T_{GI} + T_{FFT}$)</td></tr>
</table>
</td></tr>
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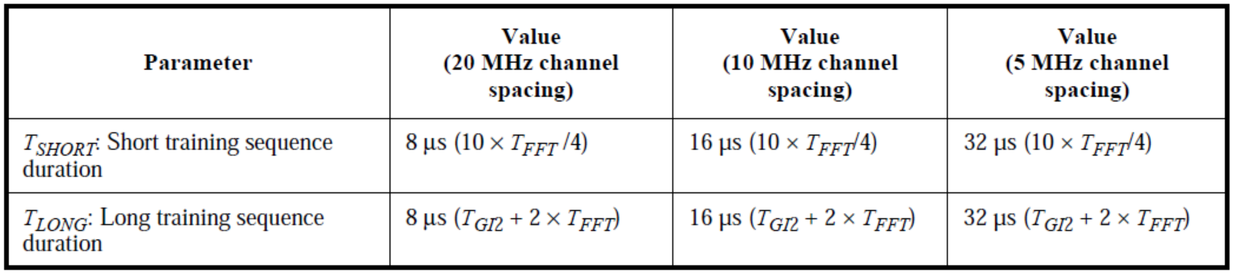
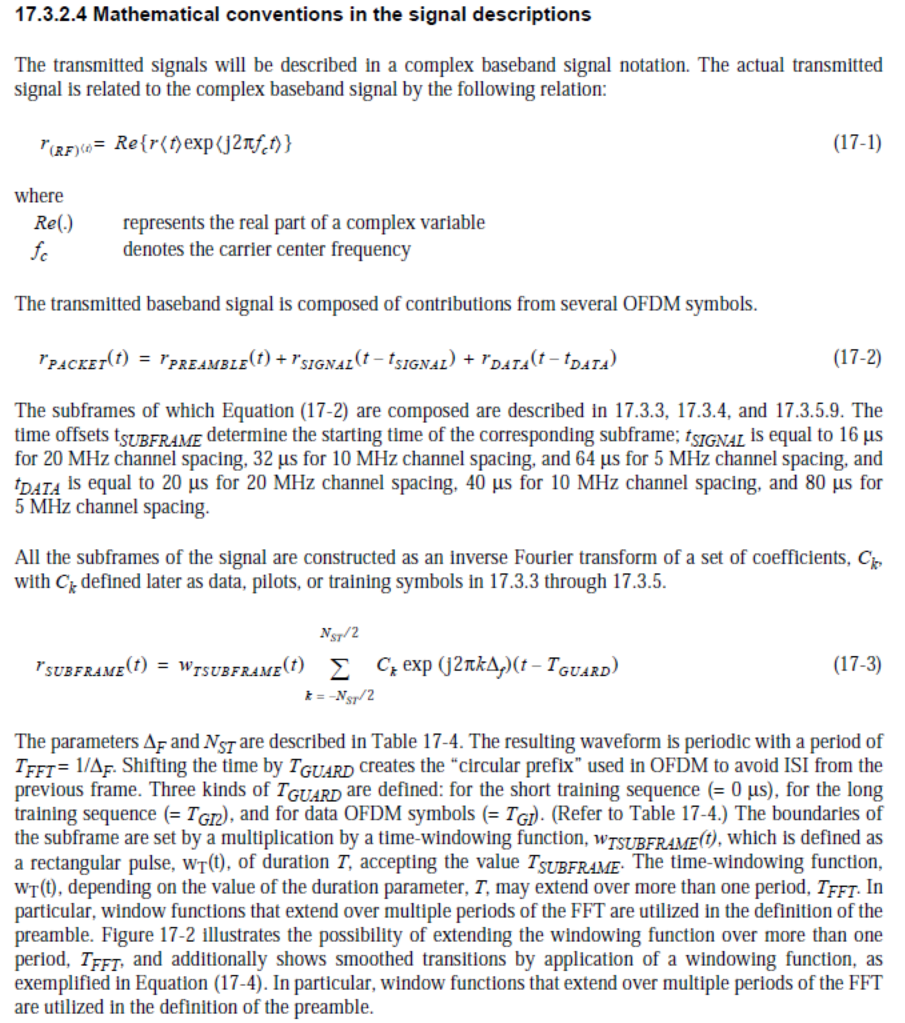
<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 μs (10 × T_{FFT} /4)</td><td>16 μs (10 × T_{FFT}/4)</td><td>32 μs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 μs (T_{GI2} + 2 × T_{FFT})</td><td>16 μs (T_{GI2} + 2 × T_{FFT})</td><td>32 μs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable

f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

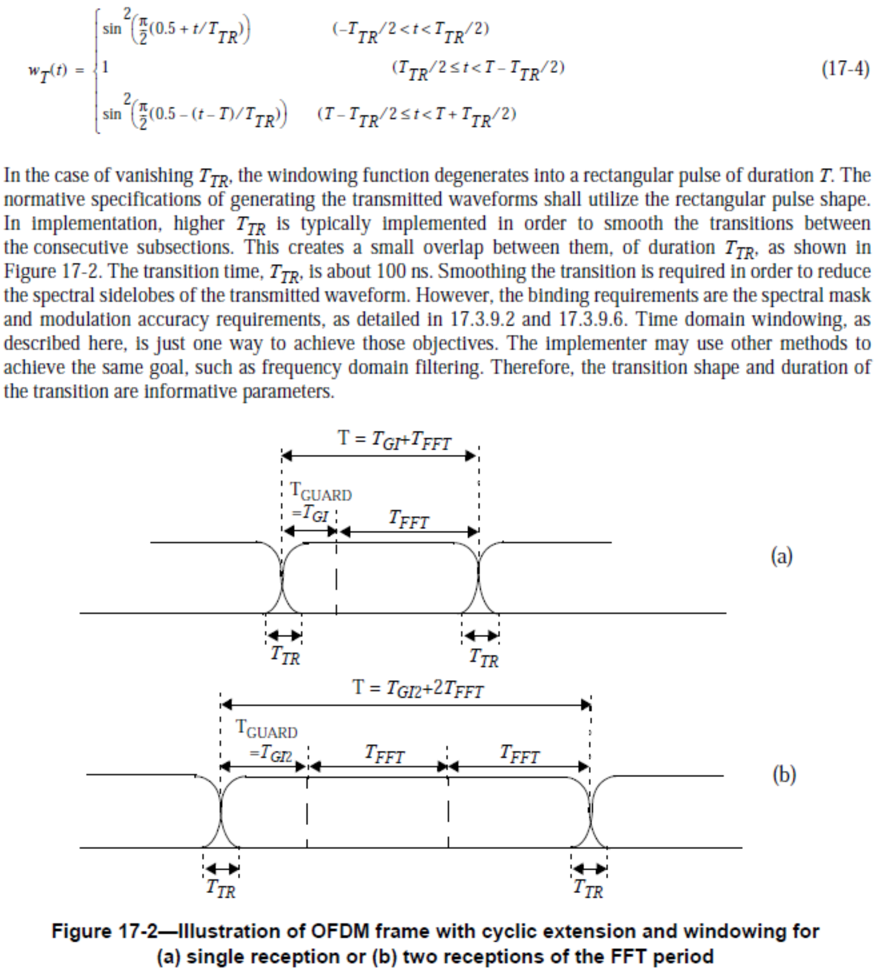
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

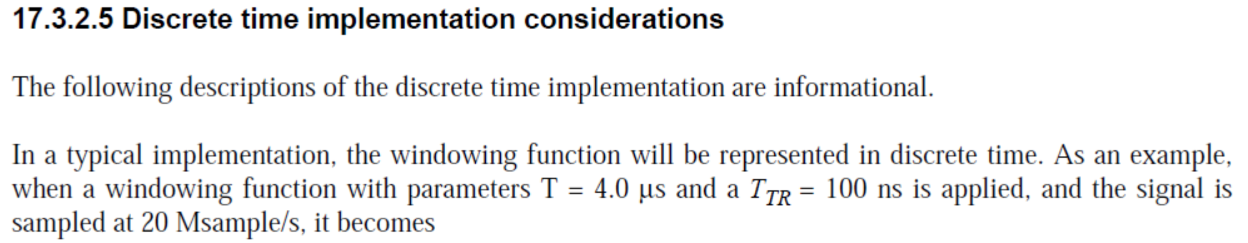
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

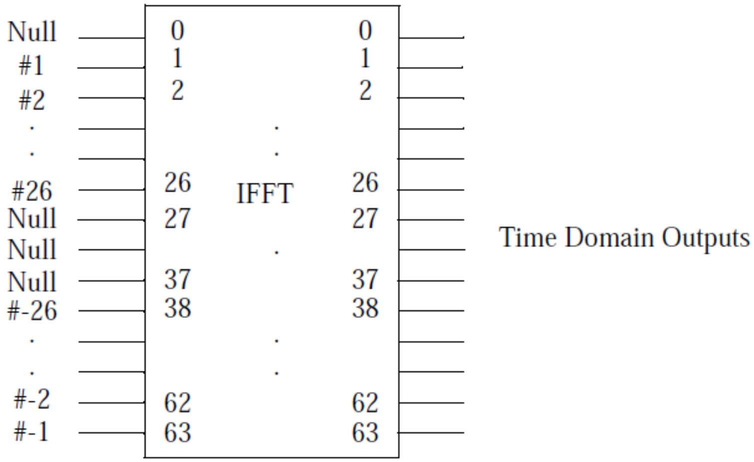
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 $$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \tag{17-4}$$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{\begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array}\right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

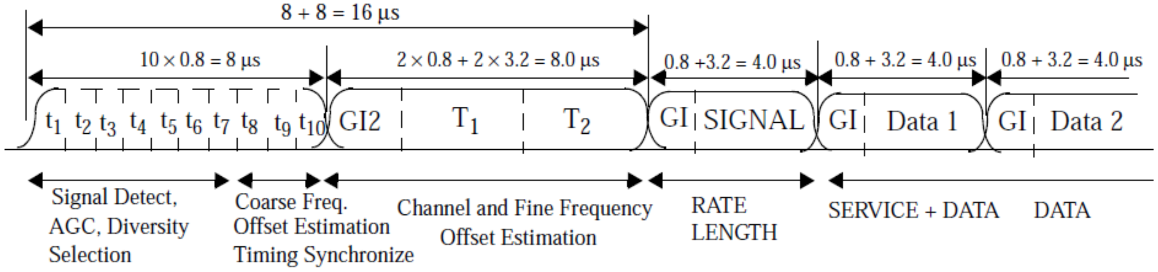
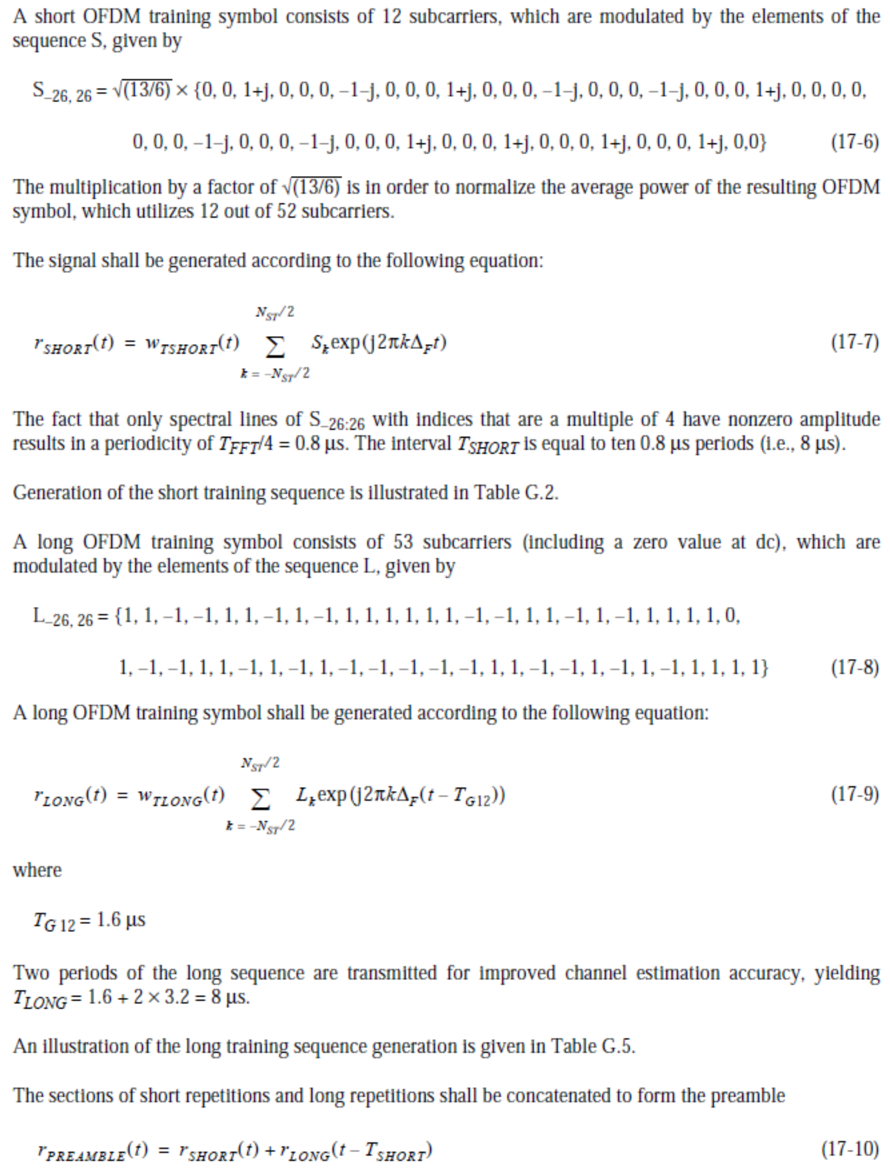


Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

</td></tr>
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

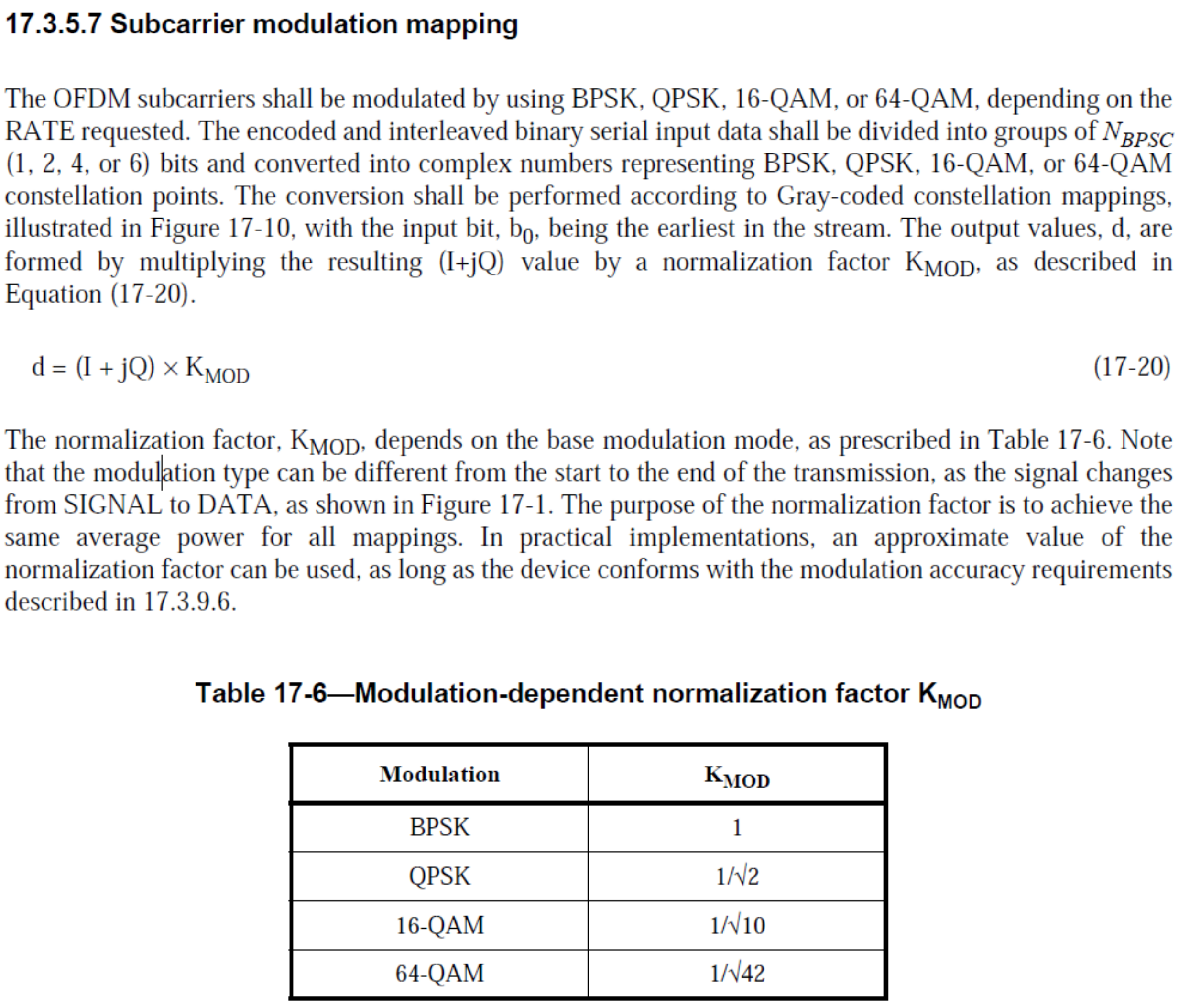
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 17 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


<h3>17.3.5.7 Subcarrier modulation mapping</h3>

<p>The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).</p>

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

<p>The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.</p>

<p>Table 17-6—Modulation-dependent normalization factor K_{MOD}</p>

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

<p>See, e.g., 802.11-2007 § 17.3.5.7</p>
</td></tr>
</table>

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$\begin{aligned} r_{DATA,n}(t) = w_{TSYM}(t) \Bigg(& \sum_{k=0}^{N_{SD}-1} d_{k,n} \exp((j2\pi M(k)\Delta_F(t - T_{GI})) \\ & + p_{n+1} \sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t - T_{GI})) \Bigg) \end{aligned} \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,\,26} = \{ & 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

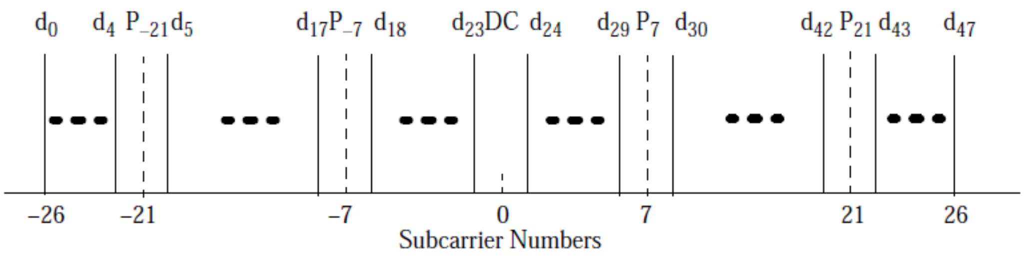


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

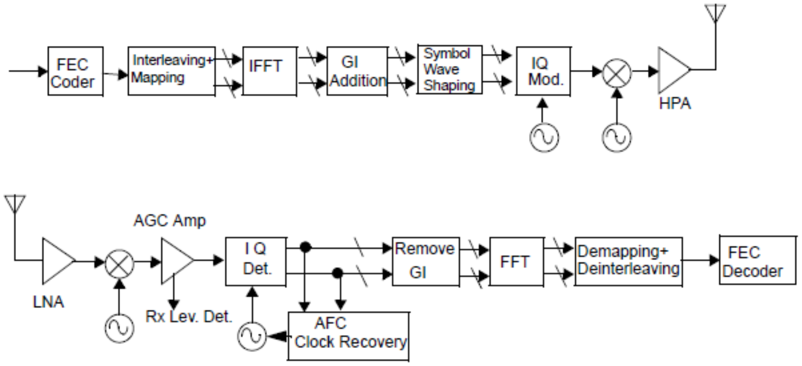


Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

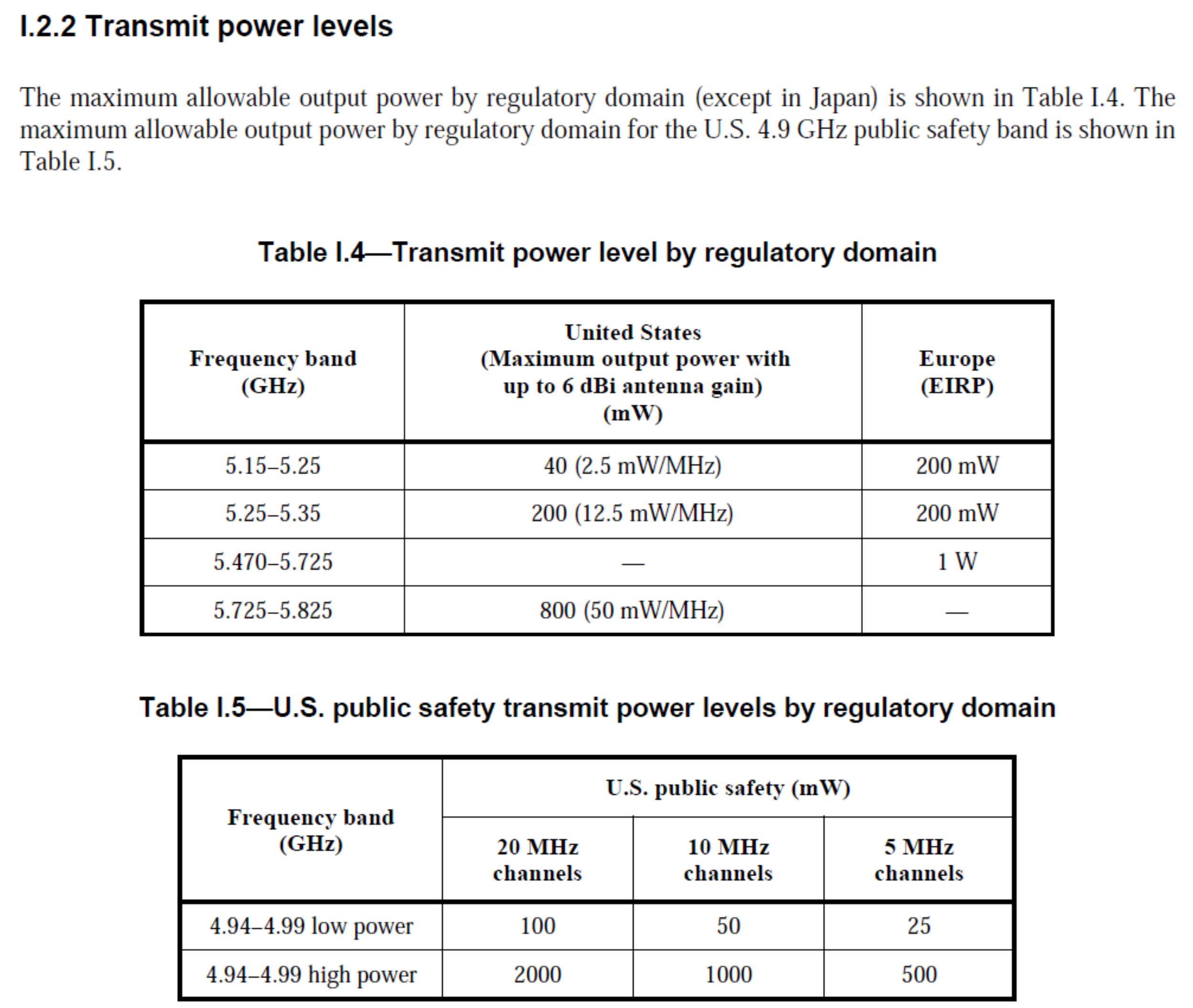
Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs[*] (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

[*] Refer to 17.3.2.4.

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

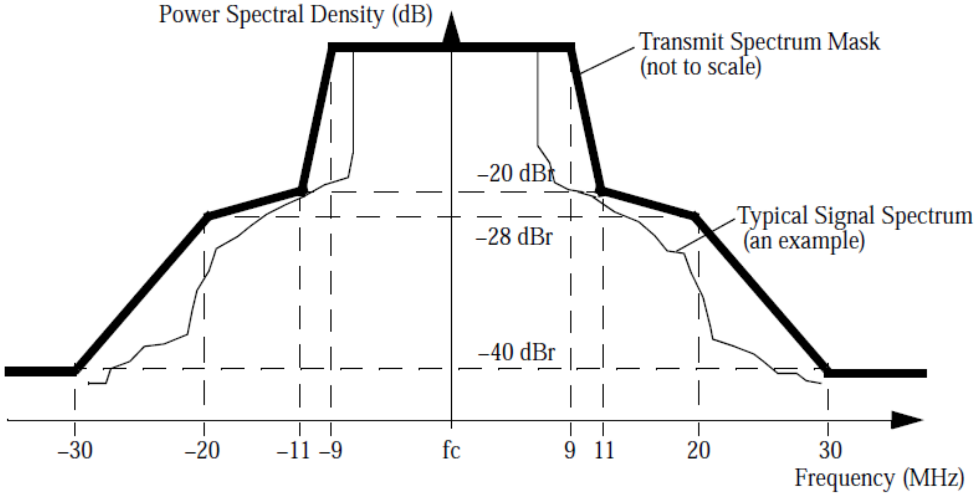
Table I.4—Transmit power level by regulatory domain

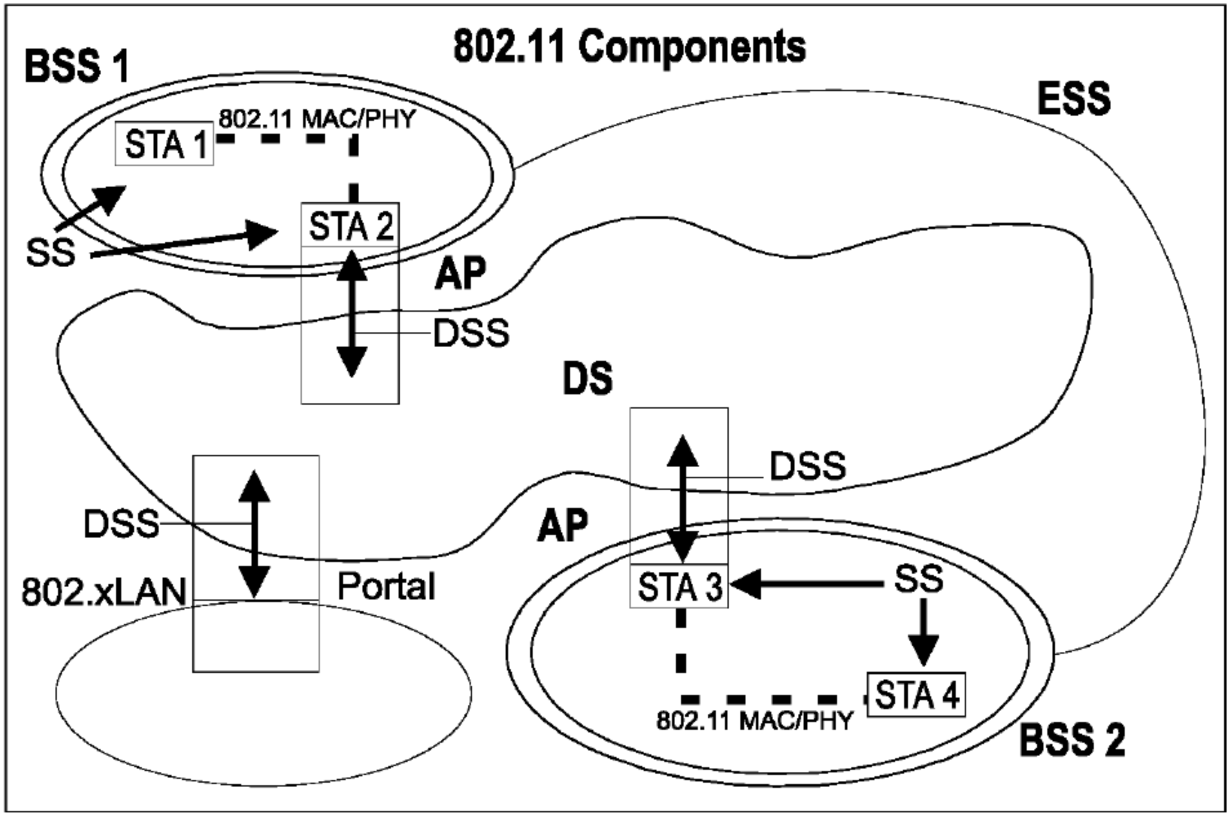
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

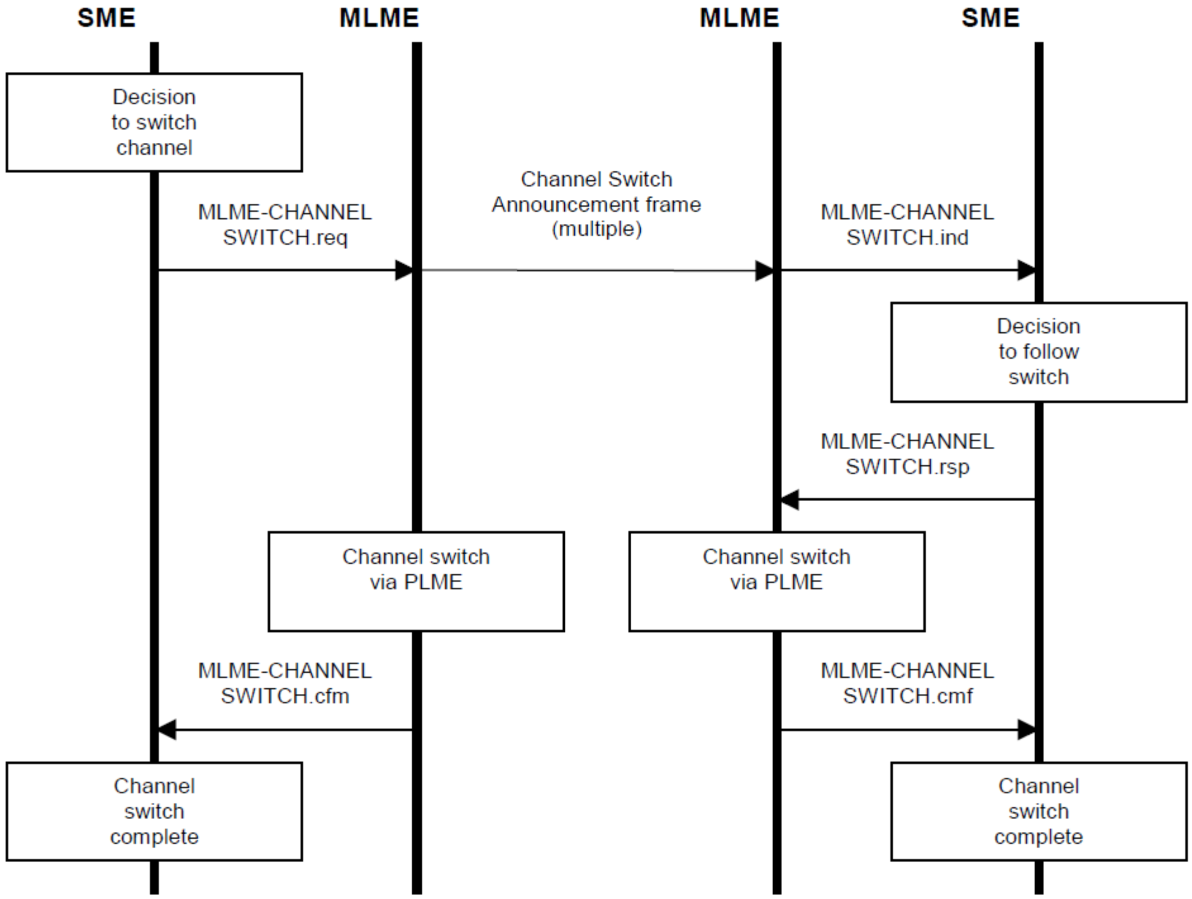
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 17 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 17 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

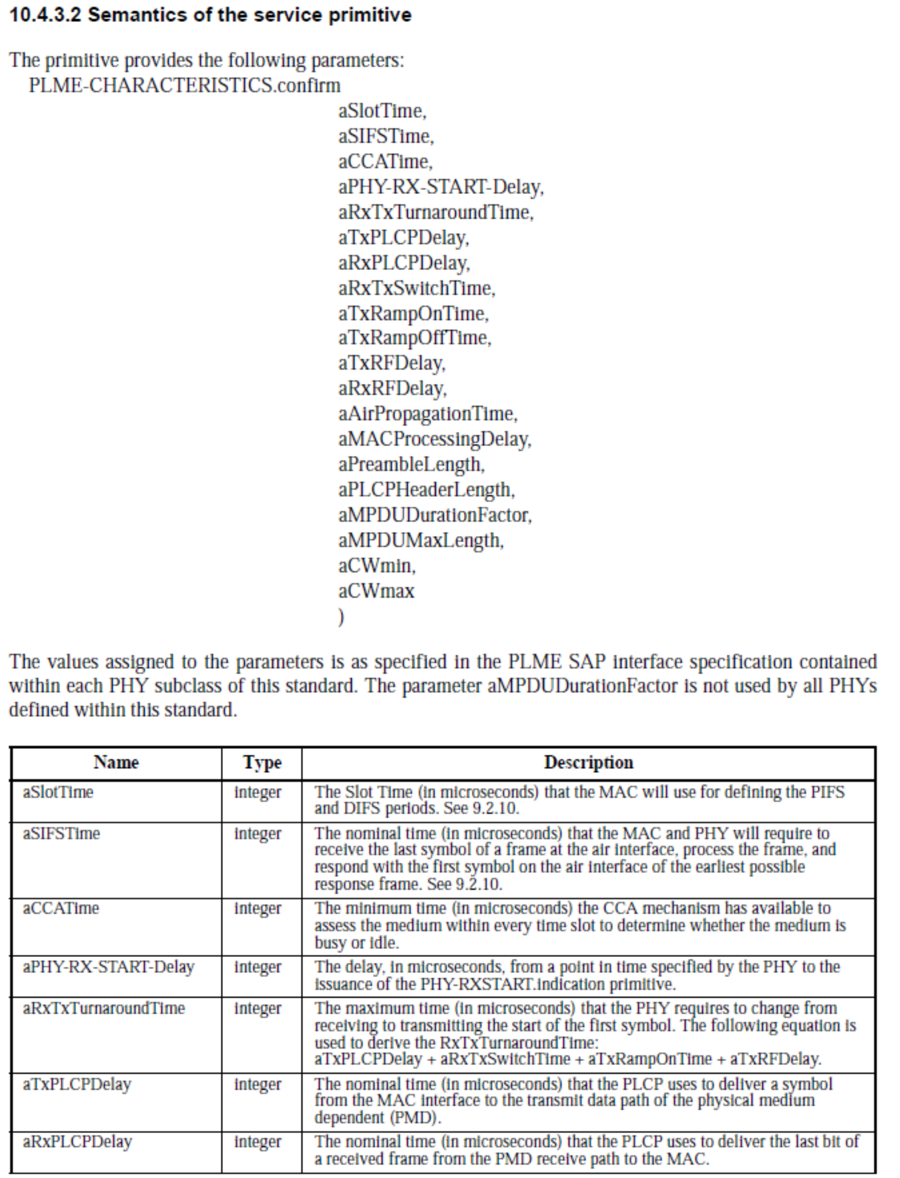
Claim 17 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 21 of the '802 Patent	**Prior Art Reference – 802.11-2007**
[21.1] The communication system of claim 17	802.11-2007 discloses all the elements of claim 17 for all the reasons provided above.
[21.2] wherein the first data of the first digital signal is encoded using a first wireless protocol and the first data of the second digital signal is encoded using a second wireless protocol.	802.11-2007 discloses "wherein the first data of the first digital signal is encoded using a first wireless protocol and the first data of the second digital signal is encoded using a second wireless protocol." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	5.2.3 Distribution system (DS) concepts PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

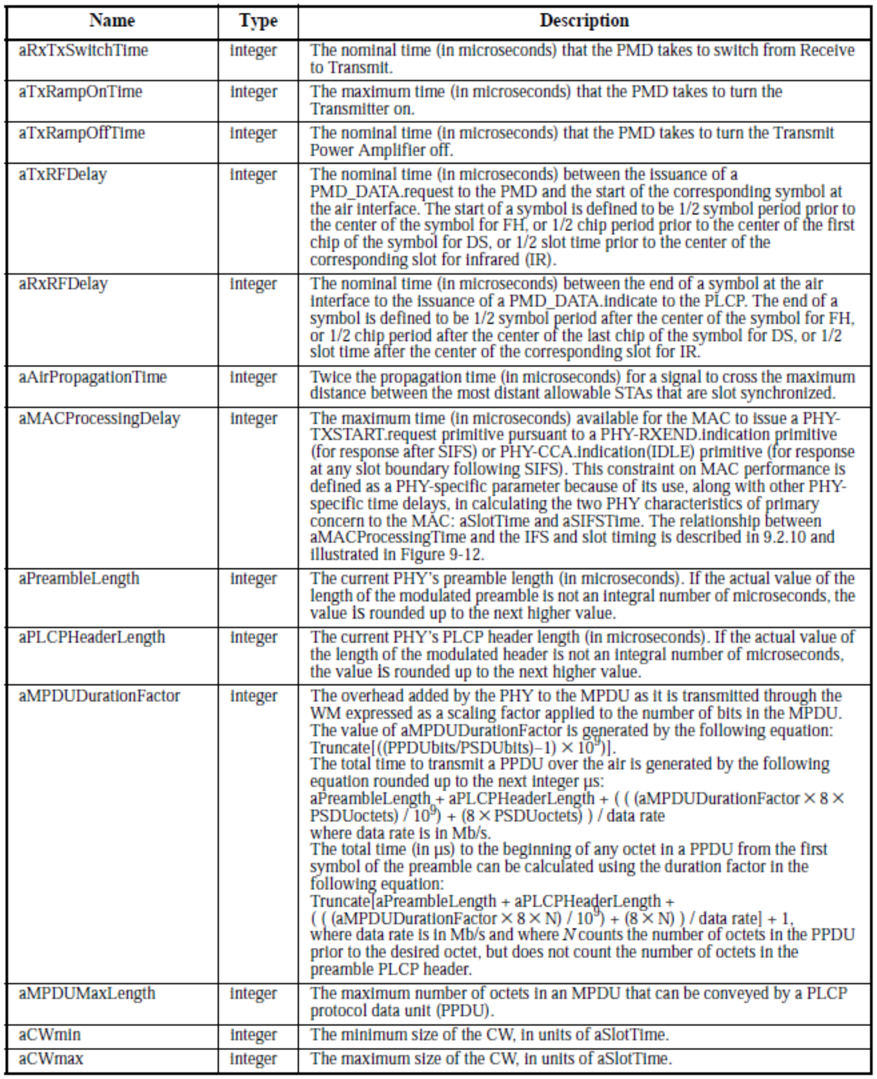
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007

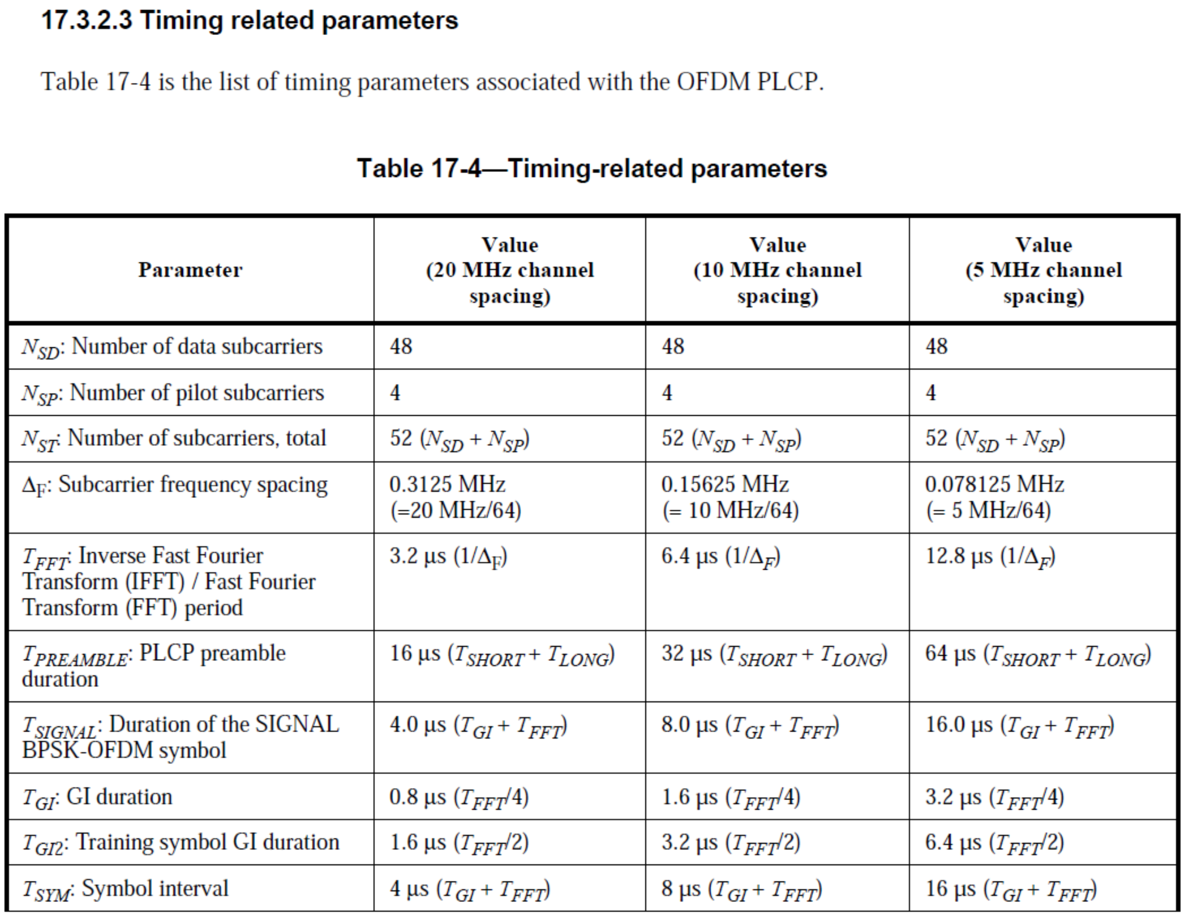


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\mathrm{Truncate}[((\mathrm{PPDUbits}/\mathrm{PSDUbits})-1) \times 10^{9})]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times \mathrm{PSDUoctets}) / 10^{9}) + (8 \times \mathrm{PSDUoctets})) / \mathrm{data\ rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\mathrm{Truncate}[\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times N) / 10^{9}) + (8 \times N)) / \mathrm{data\ rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

Claim 21 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

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<tr><th>Claim 21 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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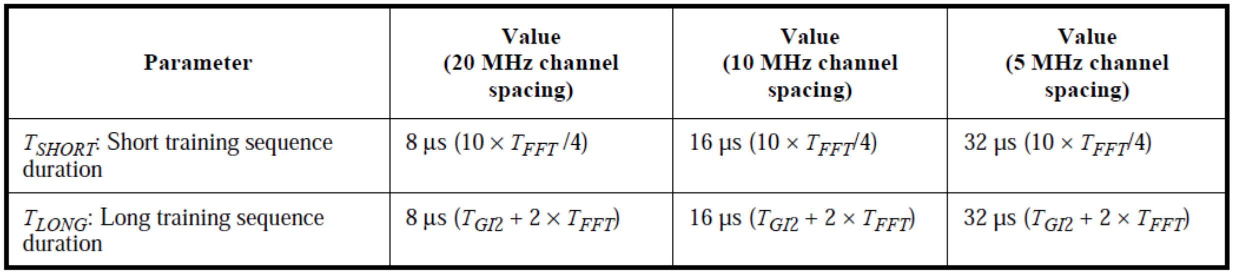
<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
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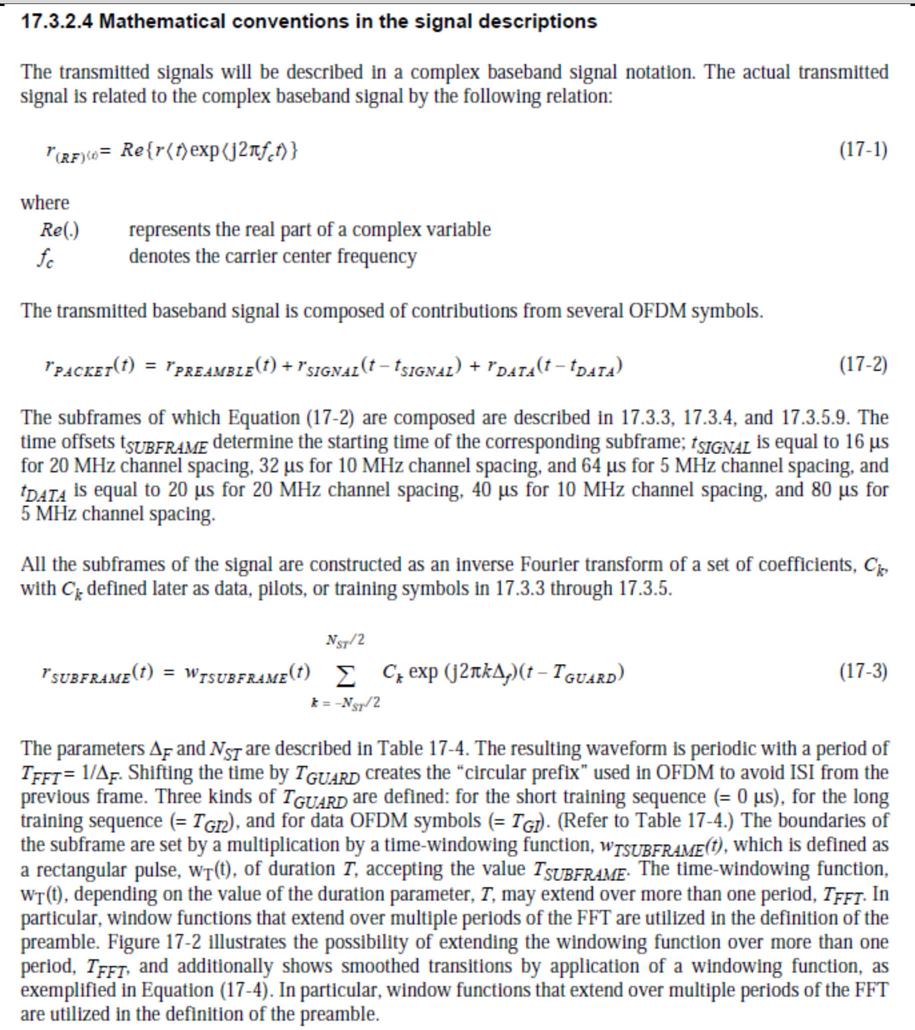
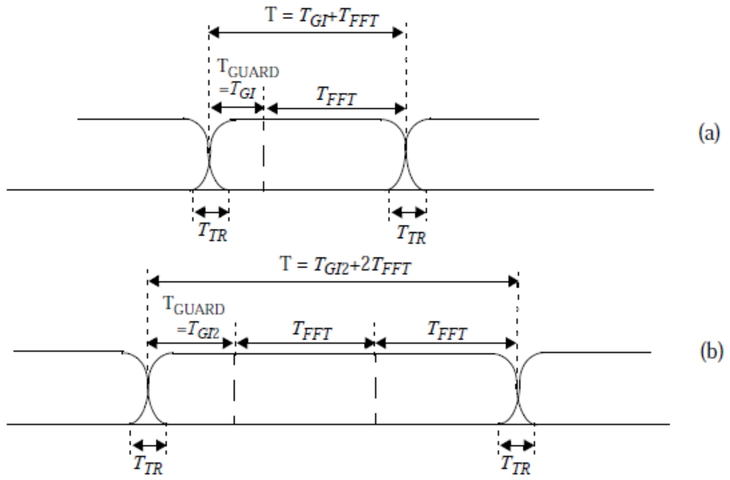
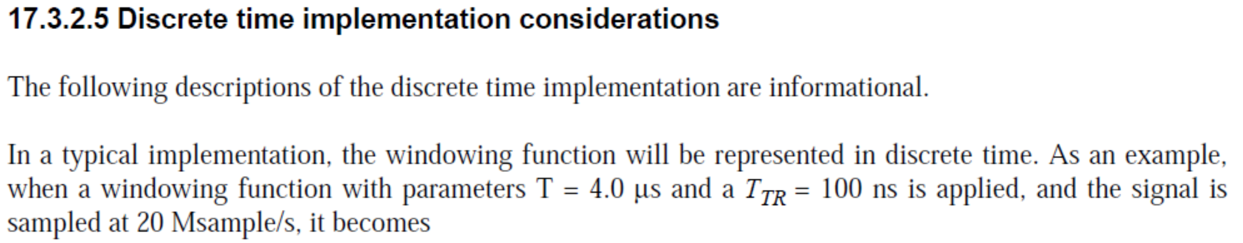
Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

<table>
<tr><th>Claim 21 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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$$w_T[n] = w_T(nT_S) = \left\{ \begin{array}{ll} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{array} \right\} \qquad (17\text{-}5)$$

The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.

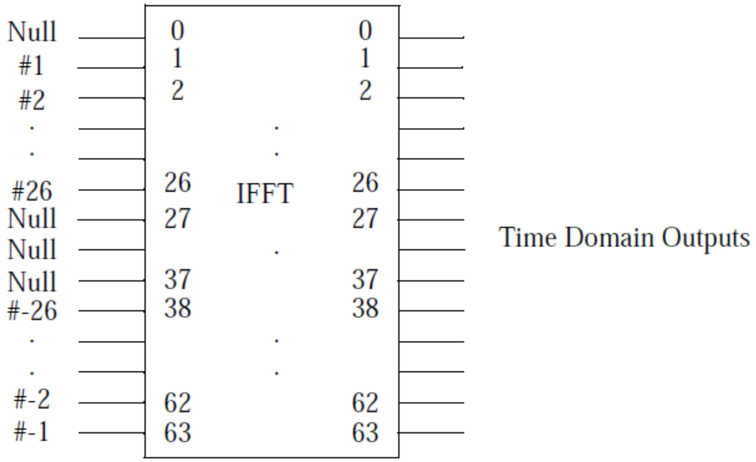
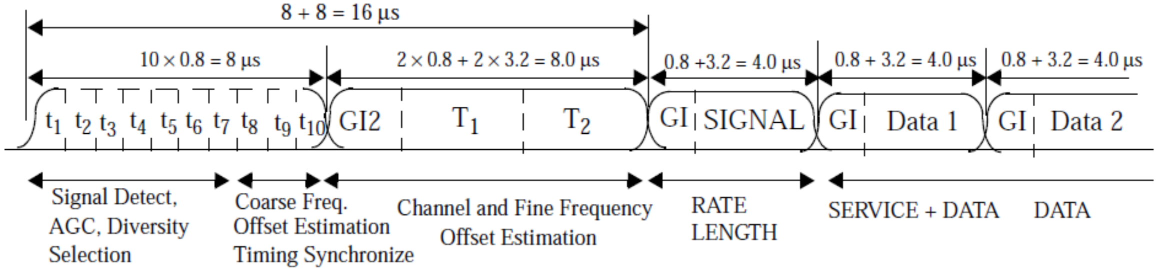
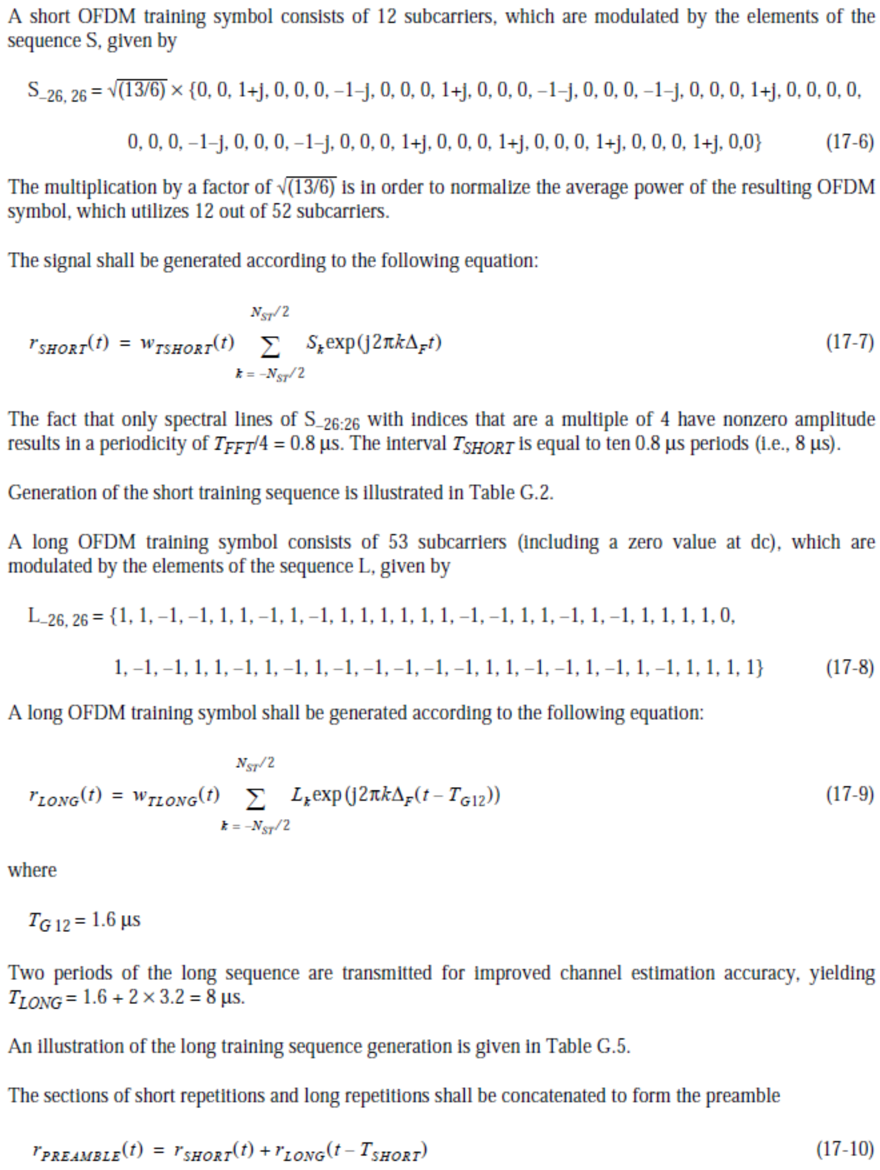


Figure 17-3—Inputs and outputs of inverse Fourier transform

See, e.g., 802.11-2007 § 17.3.2.5

</td></tr>
</table>

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G\,12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

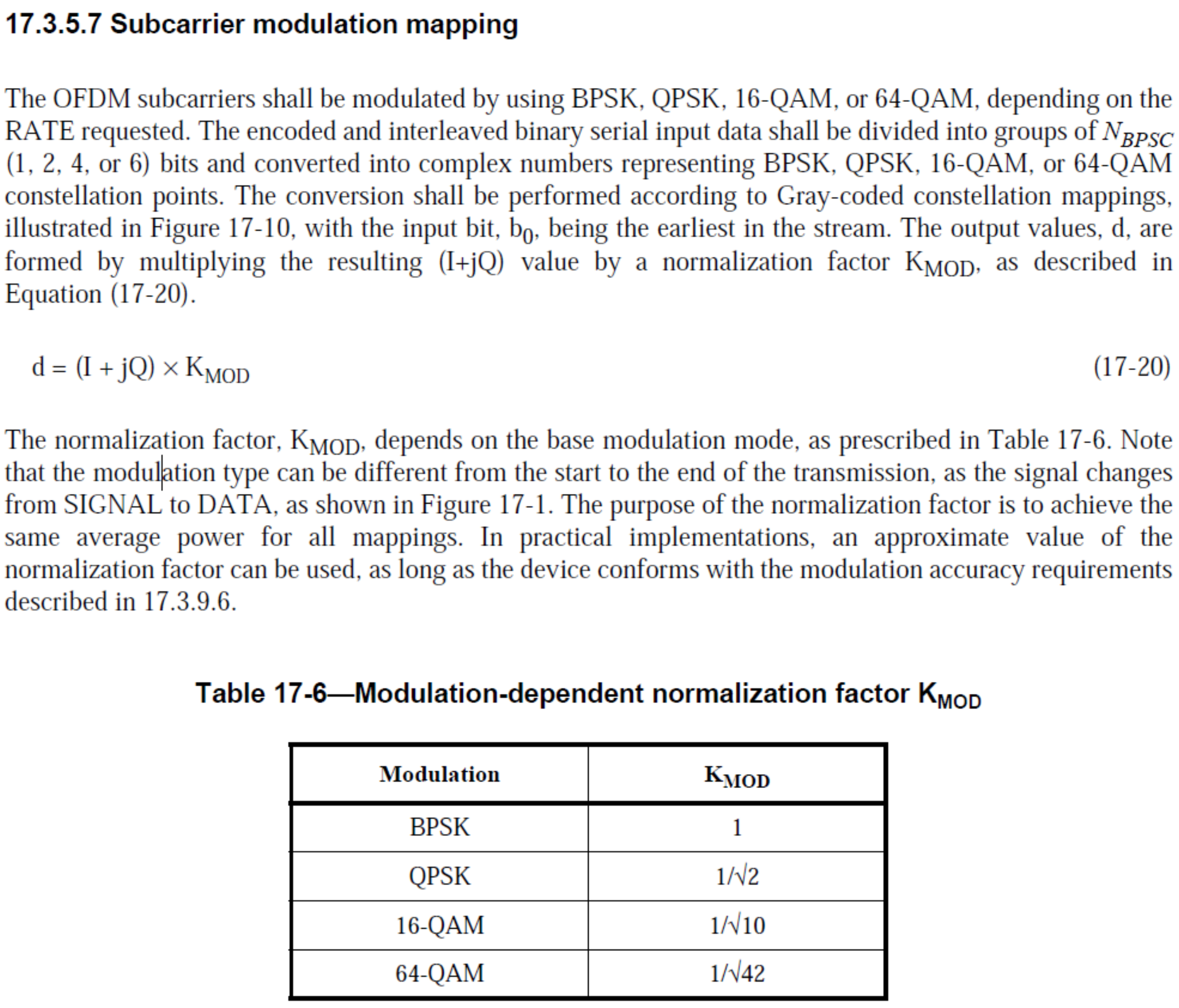
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k + N_{SD} \times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n} \exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, *M(k)*, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,\,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

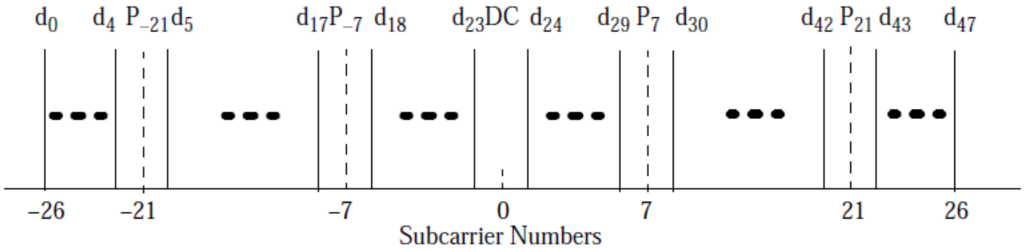


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

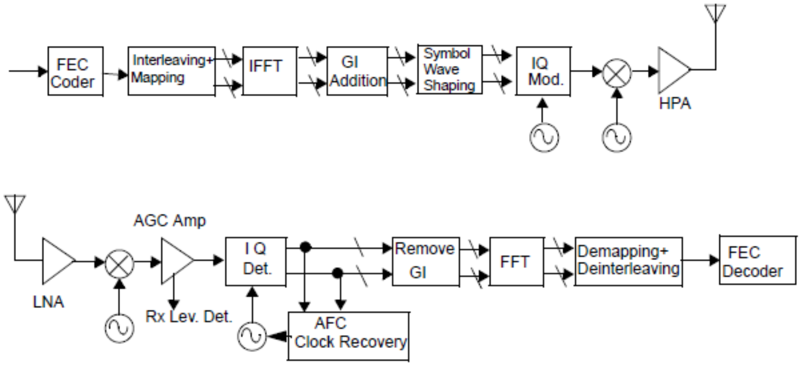


Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

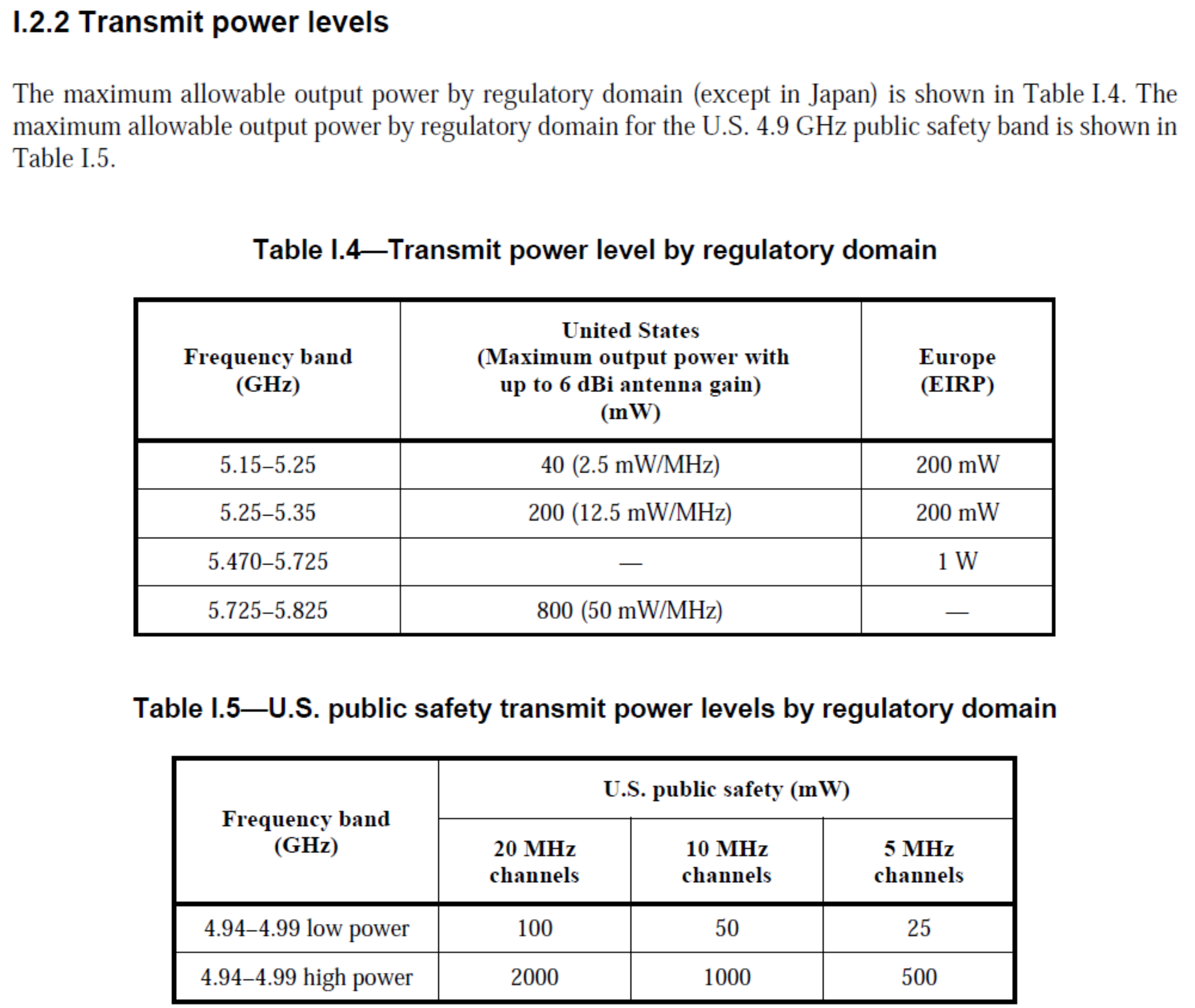
Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

Table I.4—Transmit power level by regulatory domain

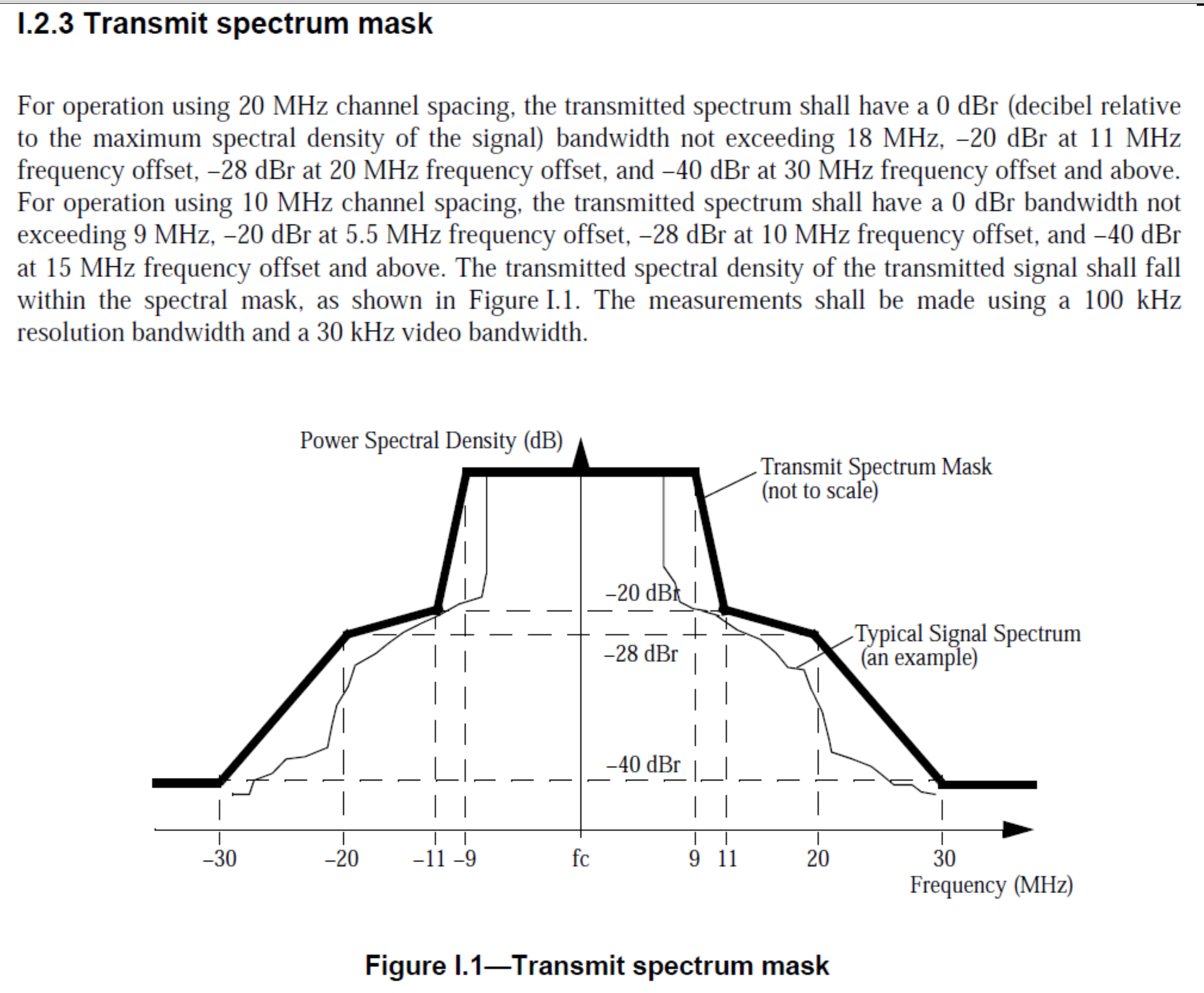
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

<table>
<tr><th>Claim 21 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



I.2.3 Transmit spectrum mask

For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

Figure I.1—Transmit spectrum mask

See, e.g., 802.11-2007 § I.2.3

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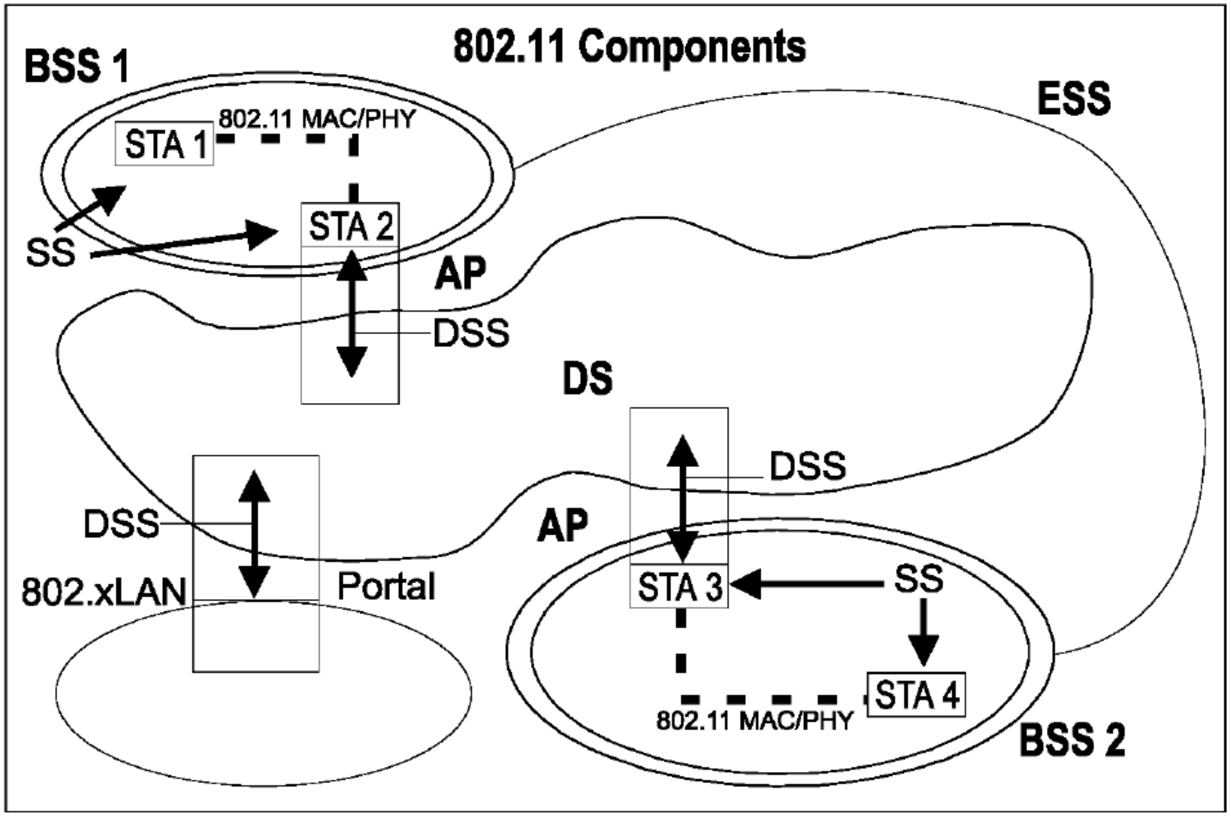
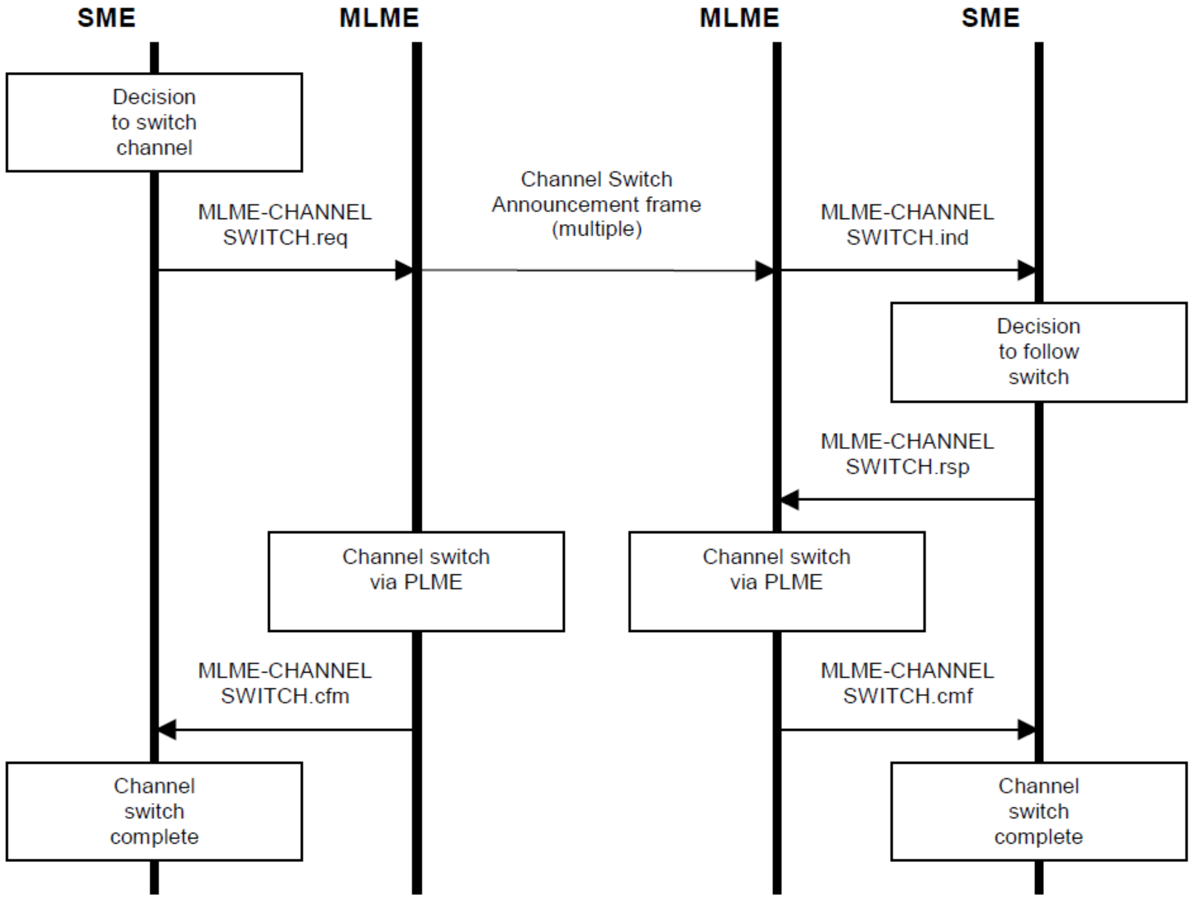
Claim 21 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

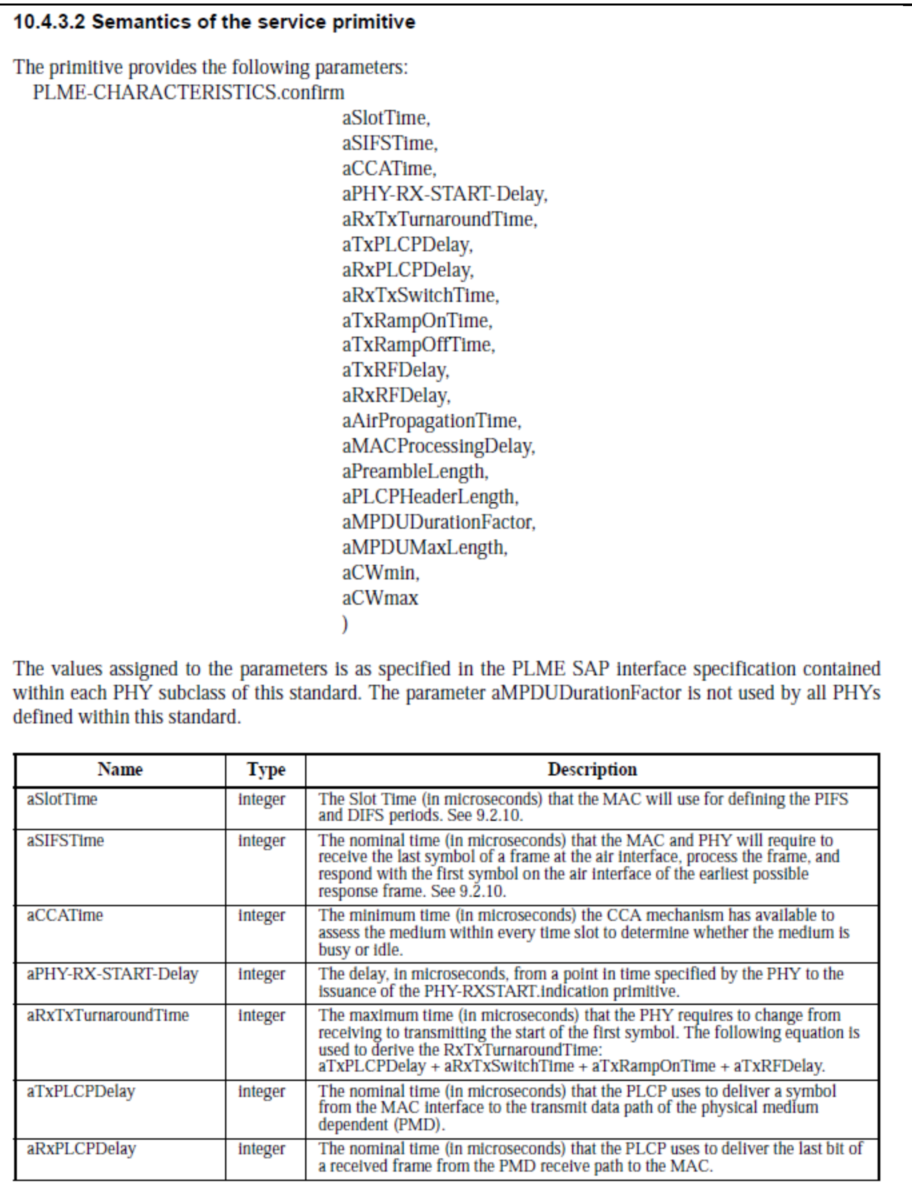
Claim 21 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 22 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
[22.1] The communication system of claim 17	802.11-2007 discloses all the elements of claim 17 for all the reasons provided above.
[22.2] wherein the second data corresponds to the first data and wherein the power amplifier outputs a third up-converted signal comprising the up-converted first analog signal and the up-converted second analog signal.	802.11-2007 discloses “wherein the second data corresponds to the first data and wherein the power amplifier outputs a third up-converted signal comprising the up-converted first analog signal and the up-converted second analog signal.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.2.3 Distribution system (DS) concepts PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

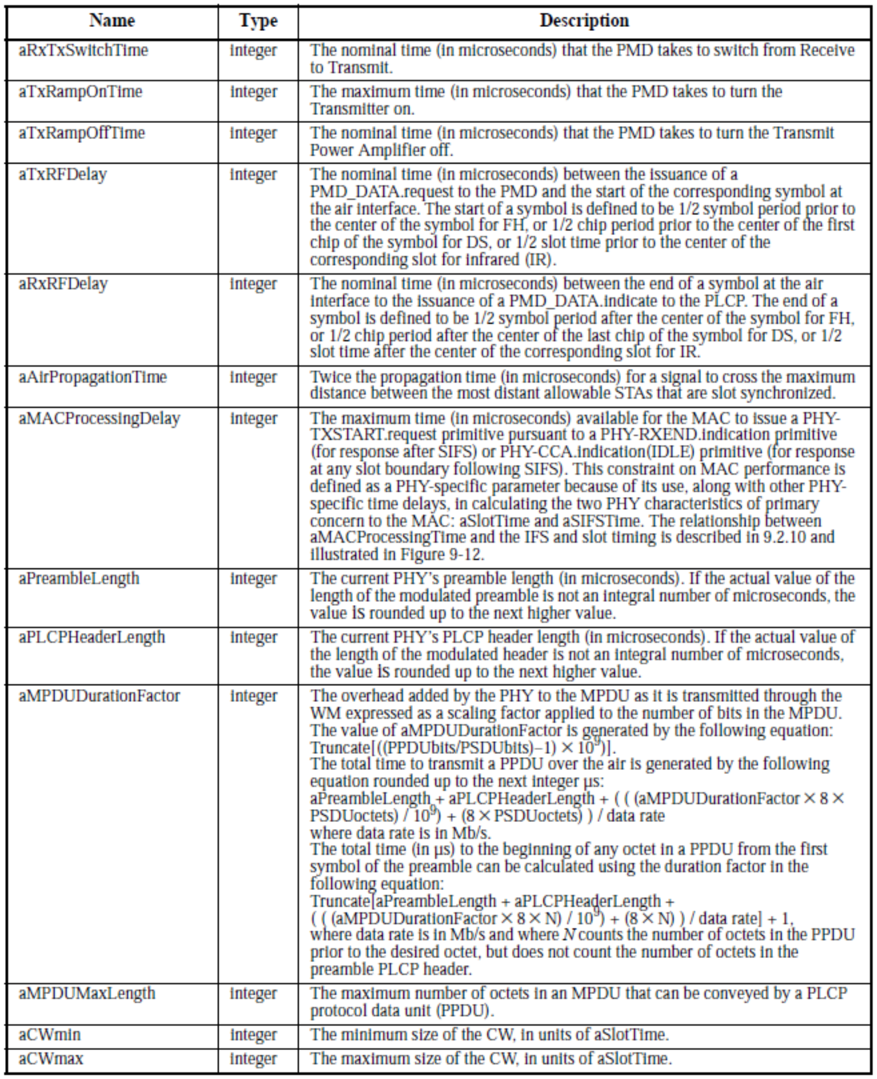
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007

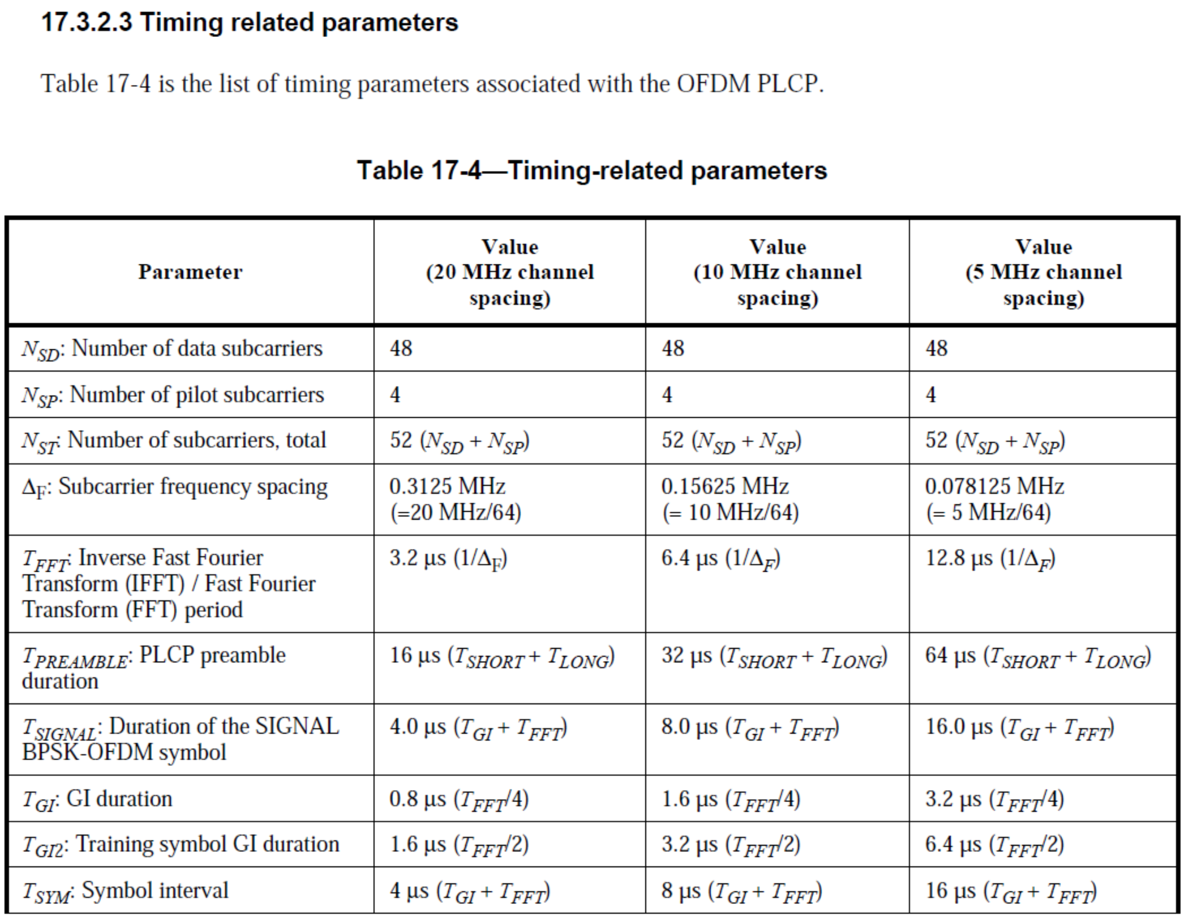


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

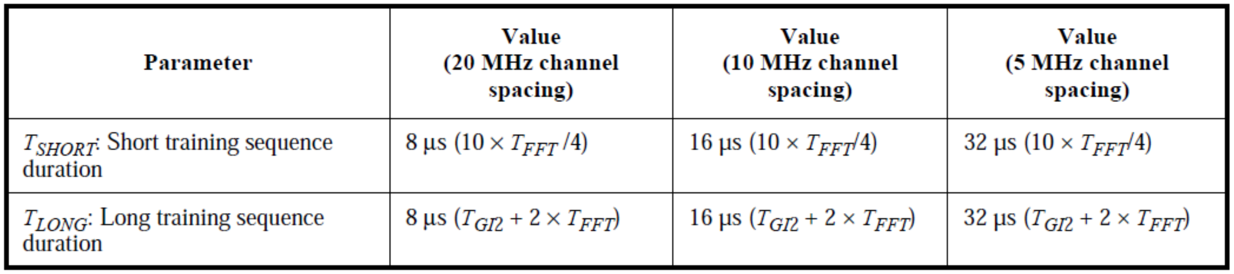
Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 22 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
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See, e.g., 802.11-2007 § 17.3.2.3
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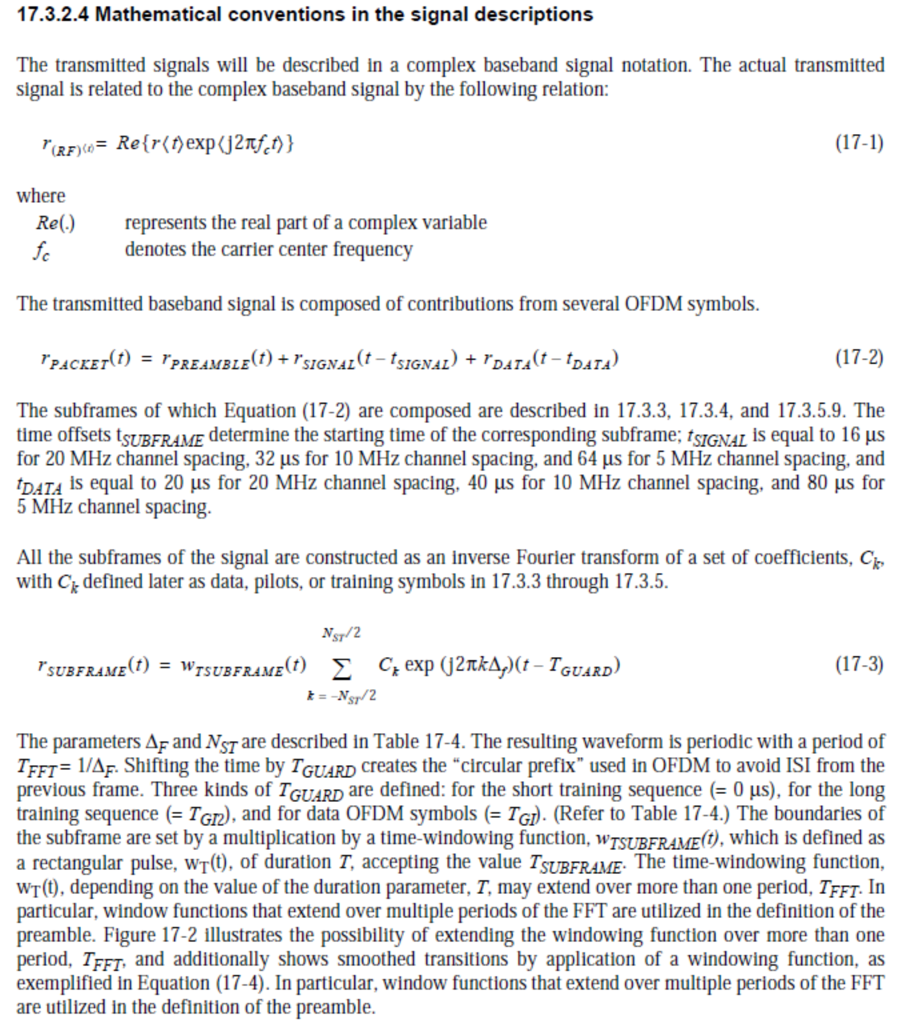
Claim 22 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \quad (17\text{-}1)$$

where

$Re(.)$	represents the real part of a complex variable
f_c	denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

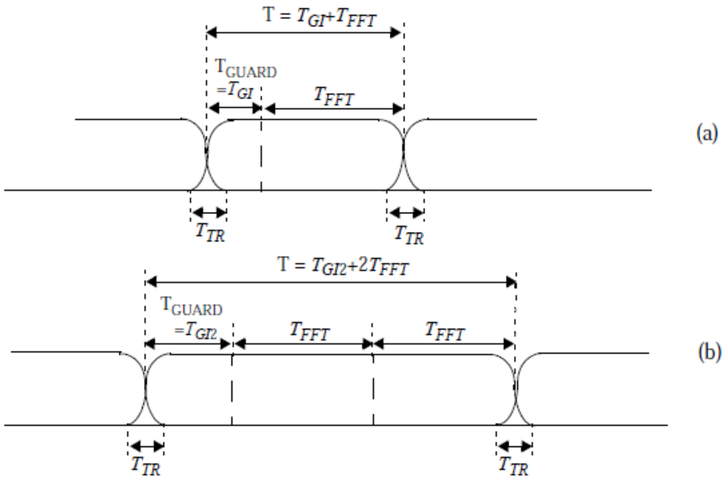
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \quad (17\text{-}2)$$

The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

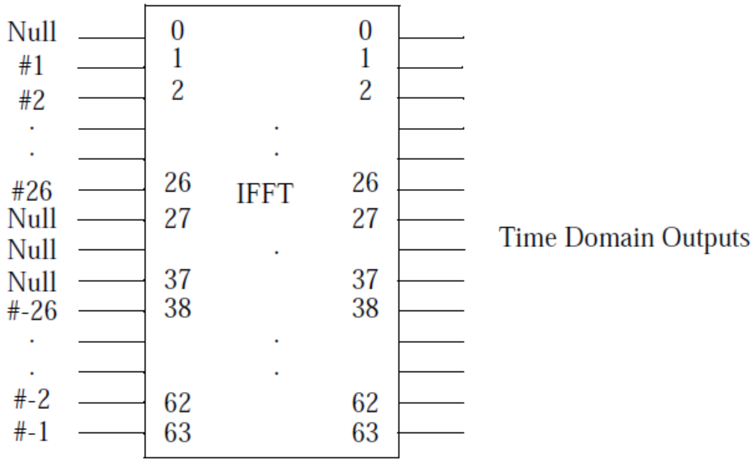
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \quad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

<table>
<tr><th>Claim 22 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
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17.3.3 PLCP preamble (SYNC)

The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.

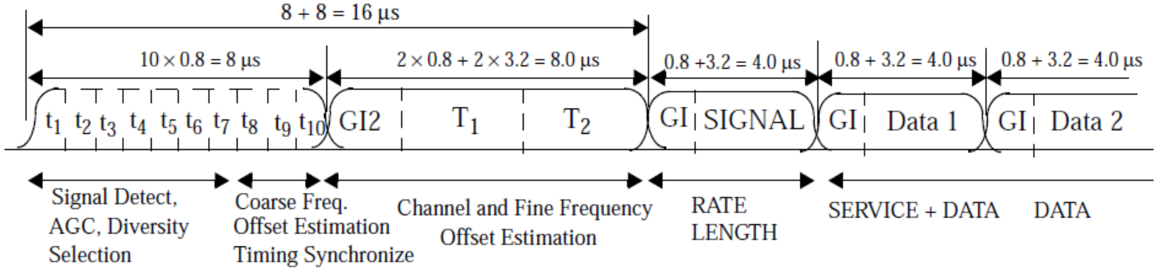

Figure 17-4—OFDM training structure

Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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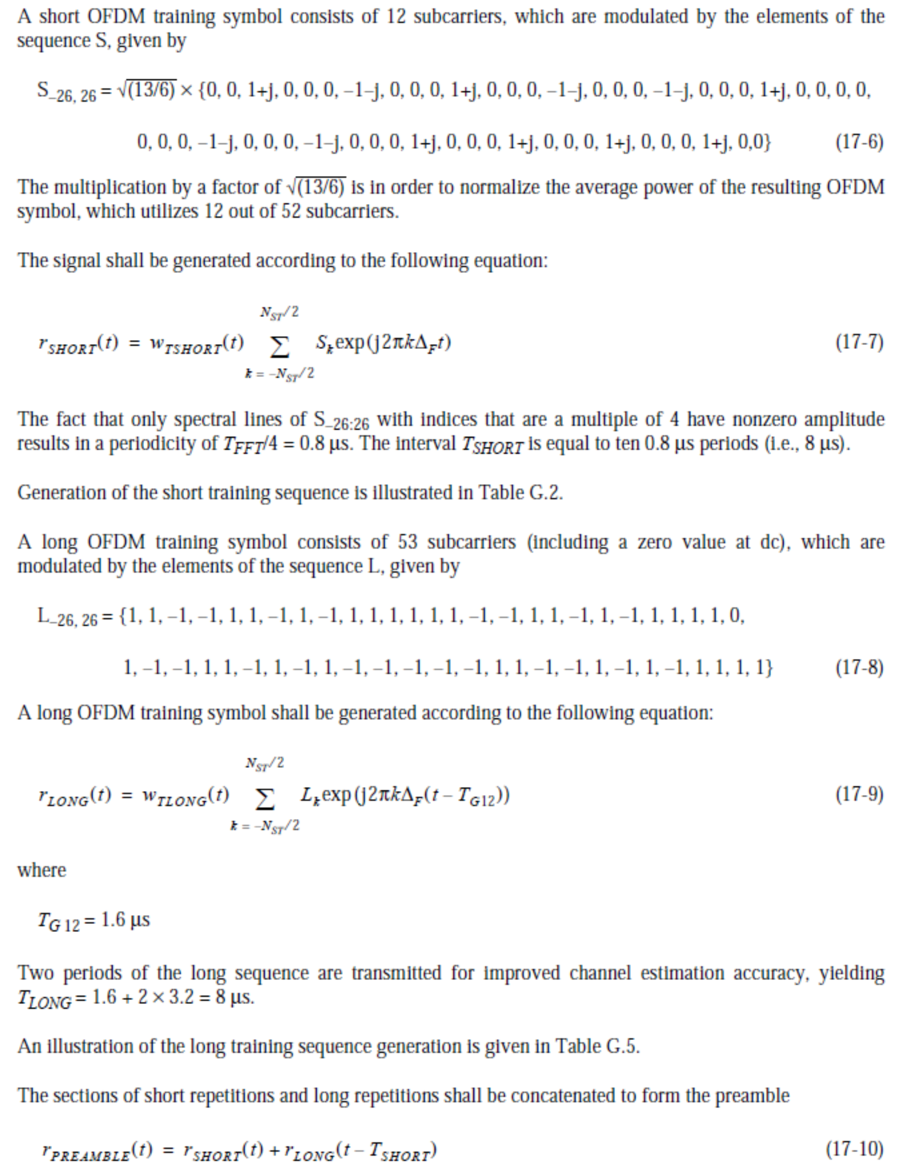
</table>



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \tag{17-6}$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \tag{17-7}$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \tag{17-8}$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F(t - T_{G12})) \tag{17-9}$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

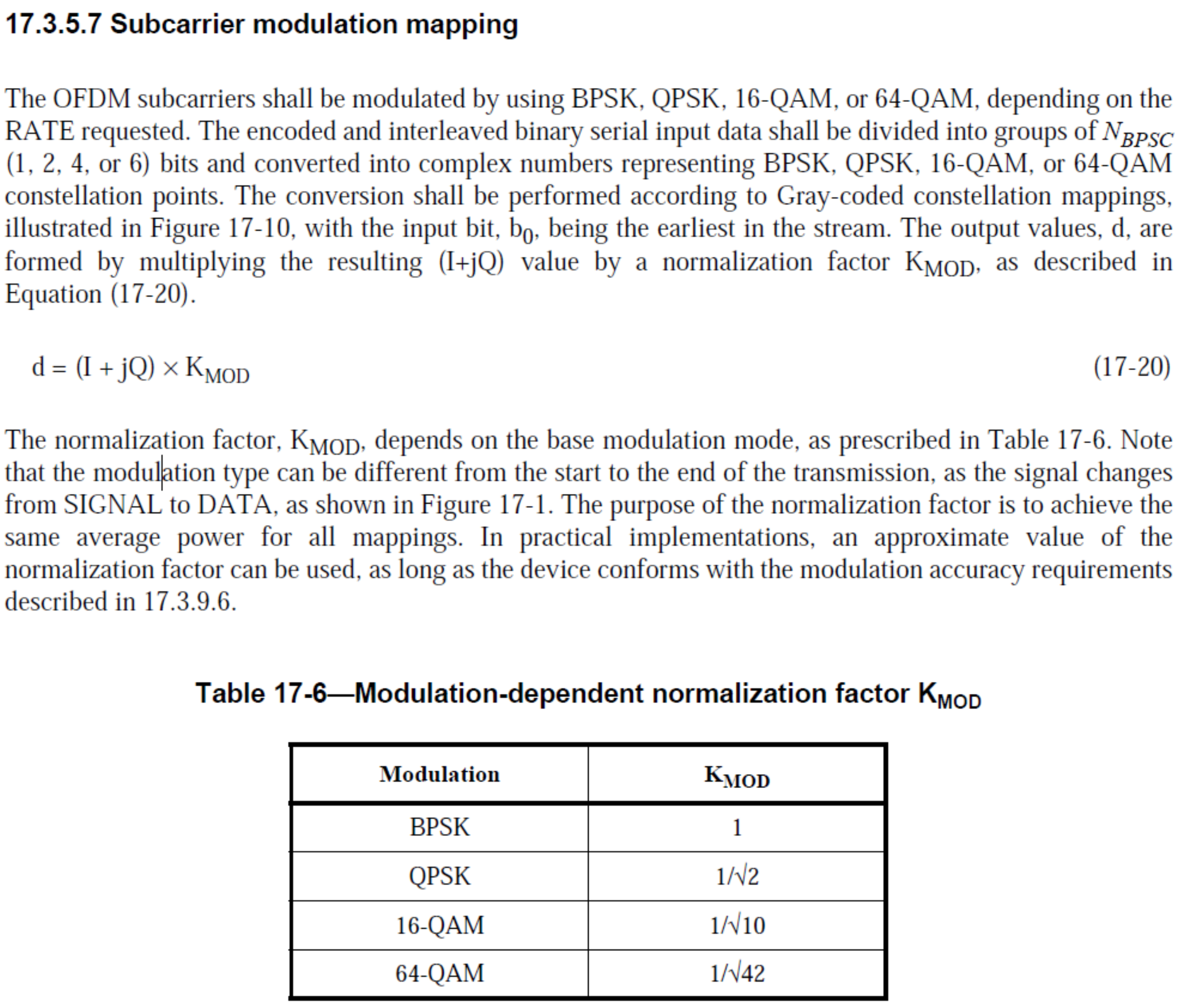
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \tag{17-10}$$

See, e.g., 802.11-2007 § 17.3.3

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See image and text below



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \tag{17-20}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1, \\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1, \\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1, \\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

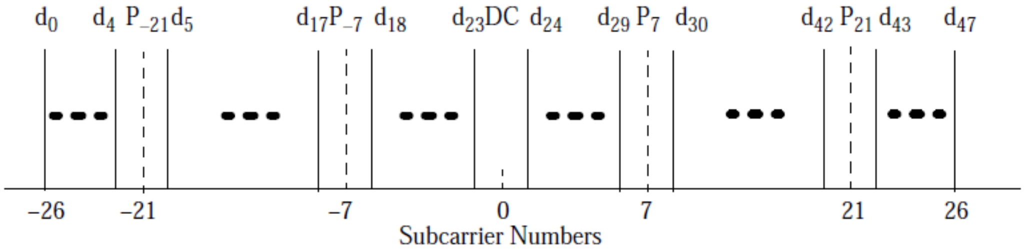


Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

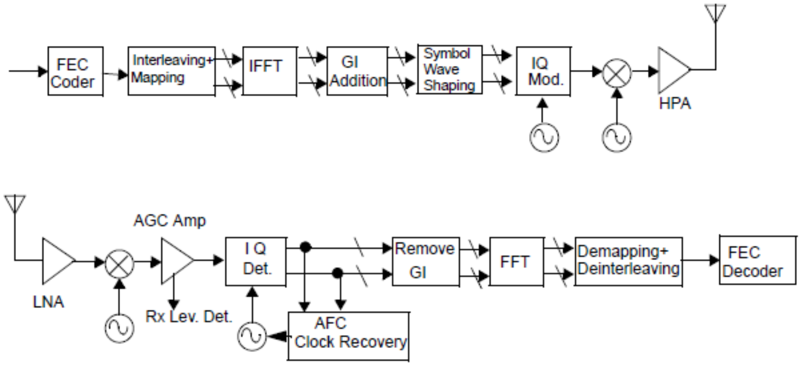


Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

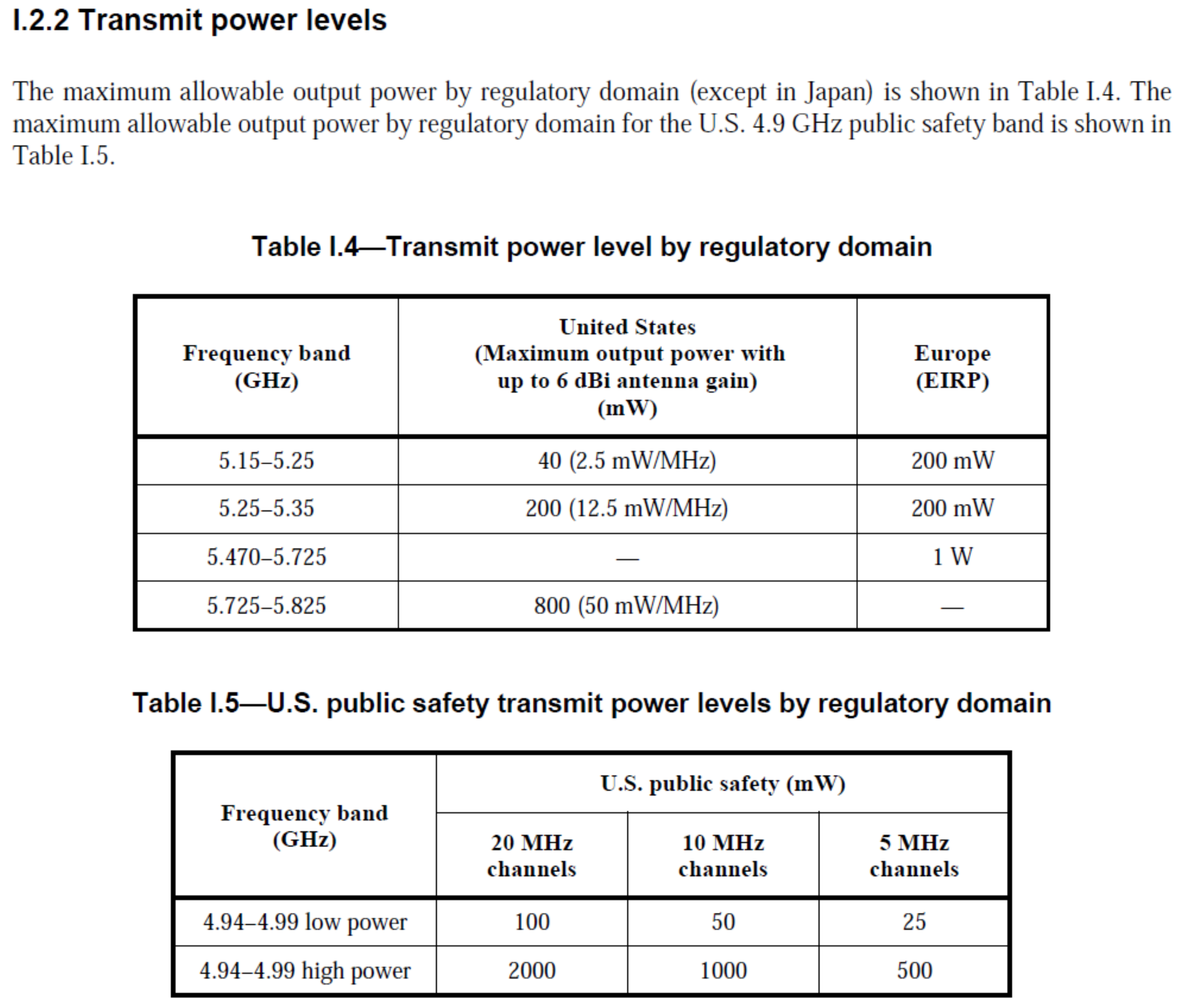
Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

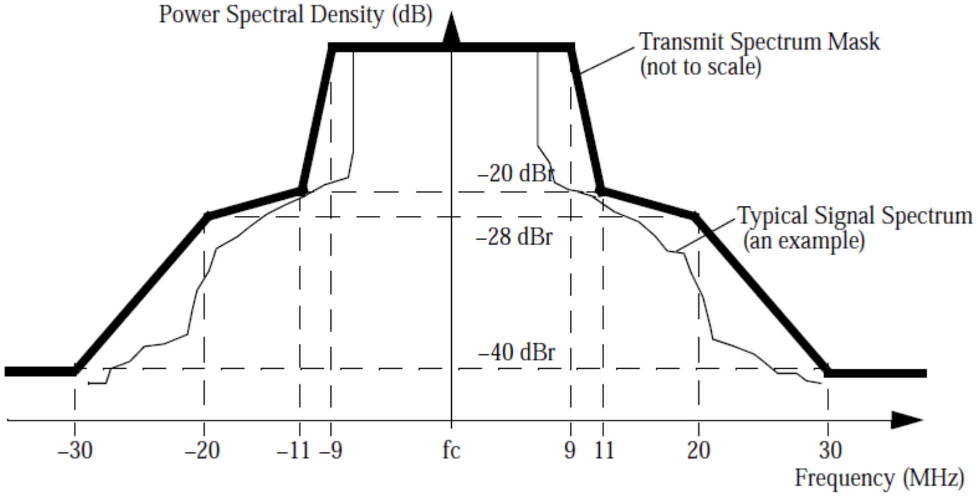
Table I.4—Transmit power level by regulatory domain

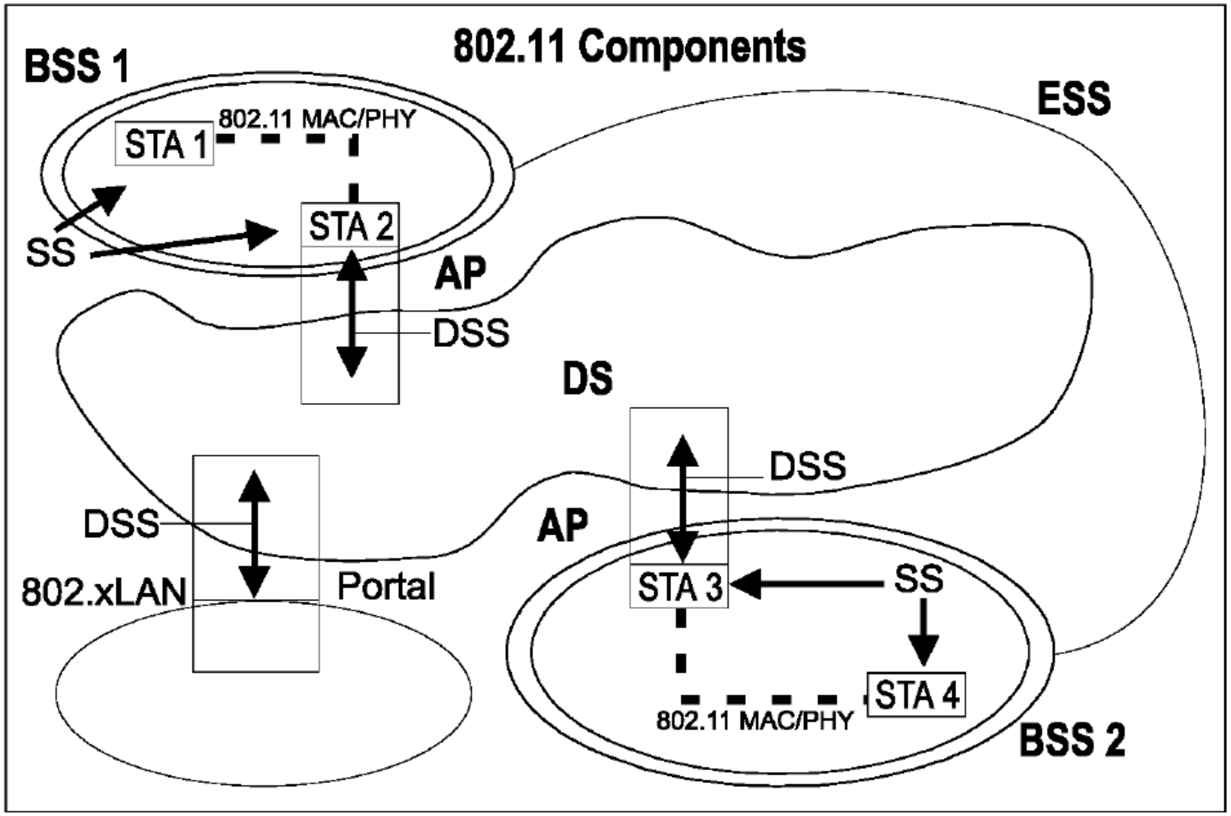
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 22 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

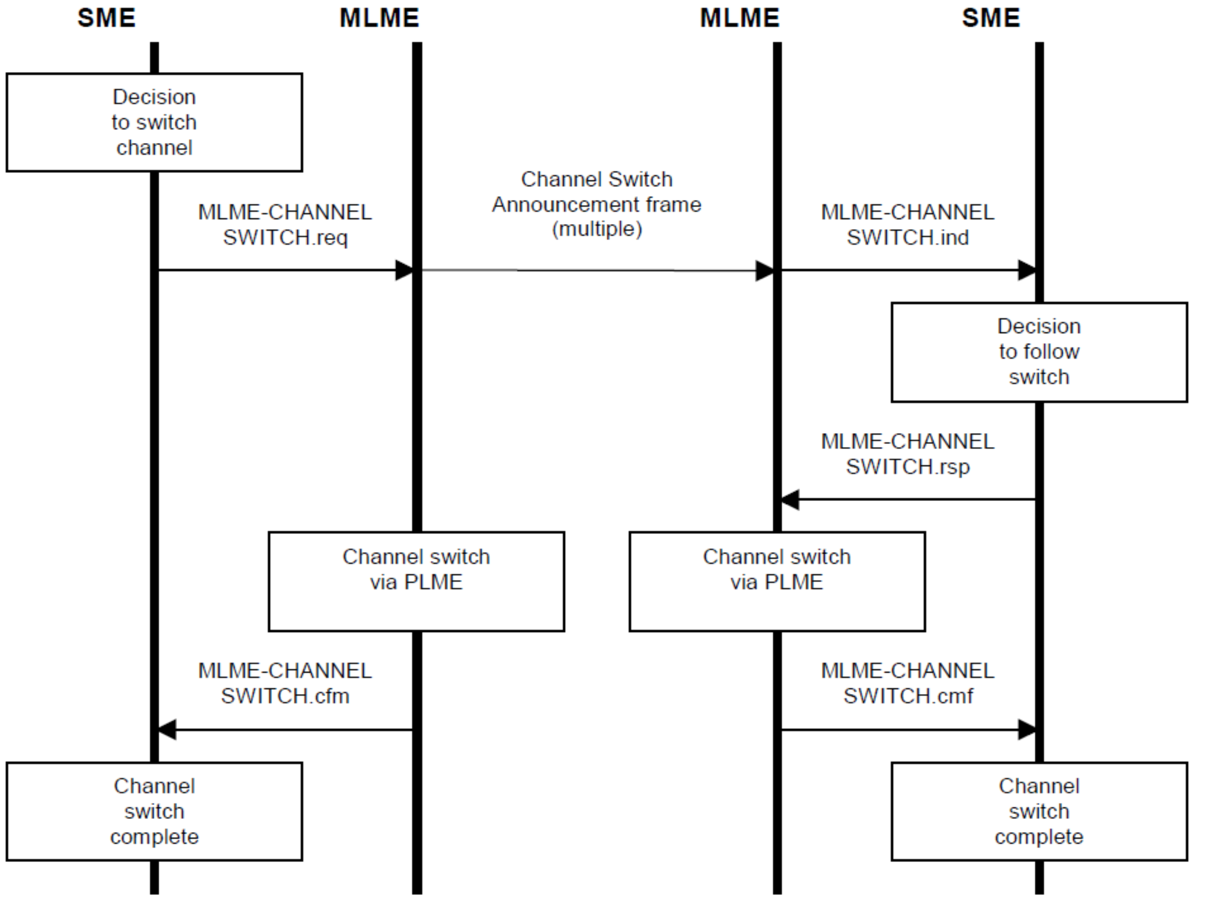
<table>
<tr><th>Claim 22 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

Figure 10-6—Channel switch

See, e.g., 802.11-2007 Figure 10-6

Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-</td></tr>
</table>

Claim 22 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 23 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
[23.1] The communication system of claim 17	802.11-2007 discloses all the elements of claim 17 for all the reasons provided above.
[23.2] wherein first and second data to be transmitted comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first up-converted frequency range and a second symbol is transmitted during the first time slot across the second up-converted frequency range, and wherein a third symbol is transmitted during a second time slot across the first up-converted frequency range and a fourth symbol is transmitted during the second time slot across a second up-converted frequency range.	802.11-2007 discloses “wherein first and second data to be transmitted comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first up-converted frequency range and a second symbol is transmitted during the first time slot across the second up-converted frequency range, and wherein a third symbol is transmitted during a second time slot across the first up-converted frequency range and a fourth symbol is transmitted during the second time slot across a second up-converted frequency range.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.

Claim 23 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

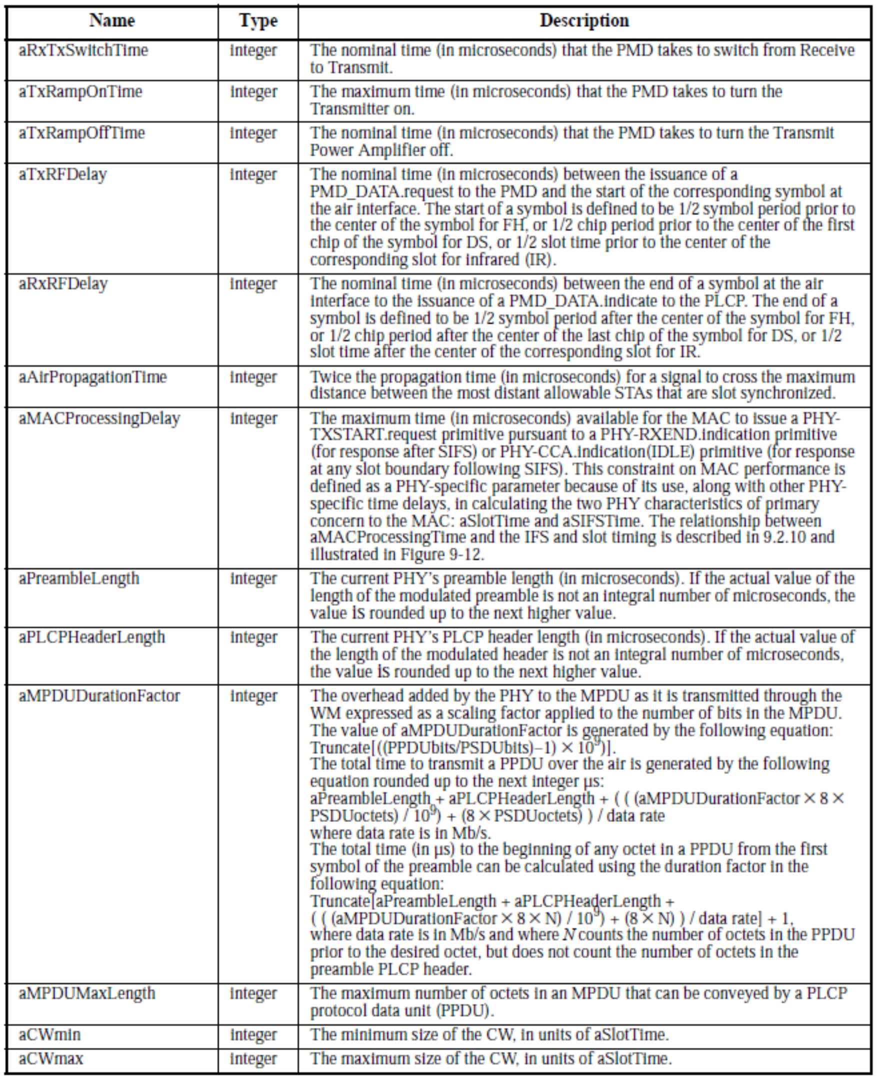
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007

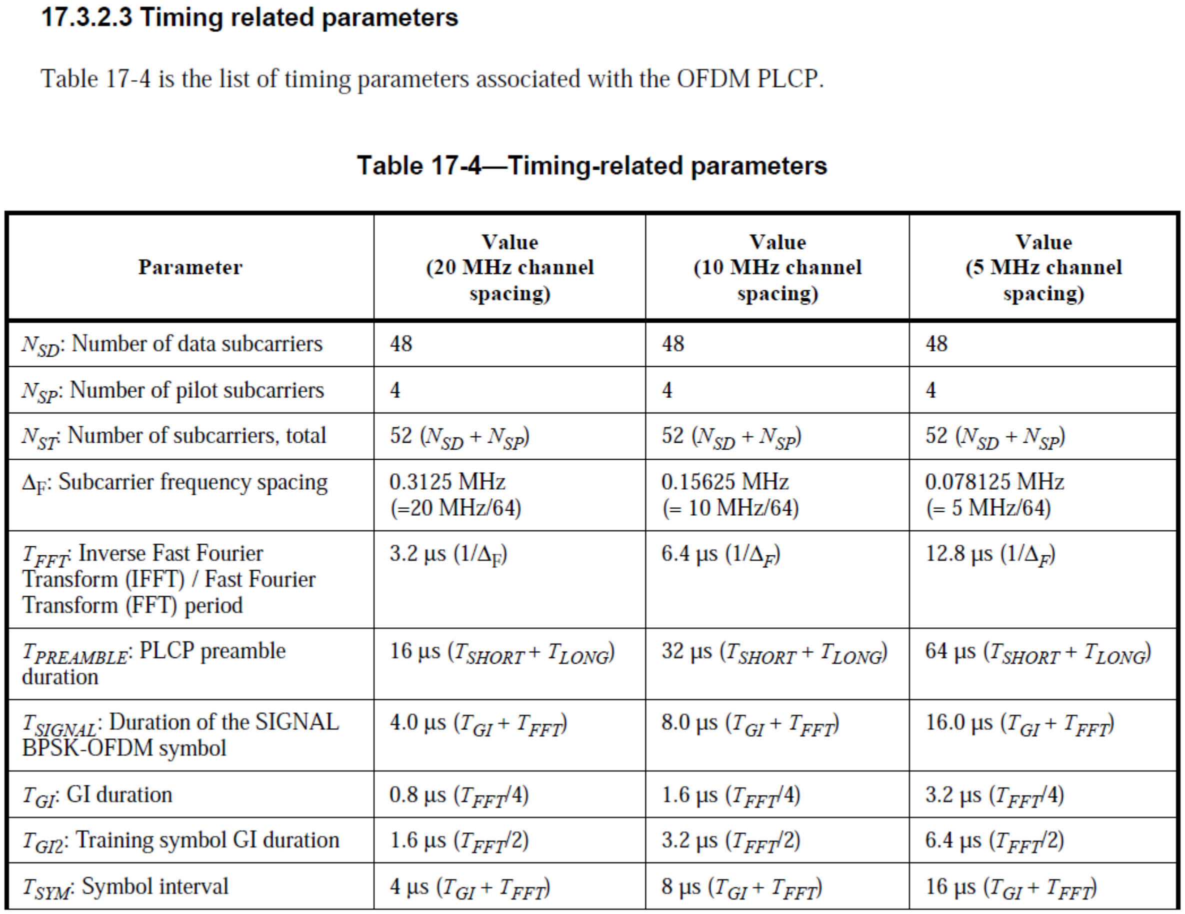


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

<table>
<tr><th>Claim 23 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz
(=20 MHz/64)</td><td>0.15625 MHz
(= 10 MHz/64)</td><td>0.078125 MHz
(= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 μs ($1/\Delta_F$)</td><td>6.4 μs ($1/\Delta_F$)</td><td>12.8 μs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 μs ($T_{SHORT} + T_{LONG}$)</td><td>32 μs ($T_{SHORT} + T_{LONG}$)</td><td>64 μs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 μs ($T_{GI} + T_{FFT}$)</td><td>8.0 μs ($T_{GI} + T_{FFT}$)</td><td>16.0 μs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 μs ($T_{FFT}/4$)</td><td>1.6 μs ($T_{FFT}/4$)</td><td>3.2 μs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 μs ($T_{FFT}/2$)</td><td>3.2 μs ($T_{FFT}/2$)</td><td>6.4 μs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 μs ($T_{GI} + T_{FFT}$)</td><td>8 μs ($T_{GI} + T_{FFT}$)</td><td>16 μs ($T_{GI} + T_{FFT}$)</td></tr>
</table>
</td></tr>
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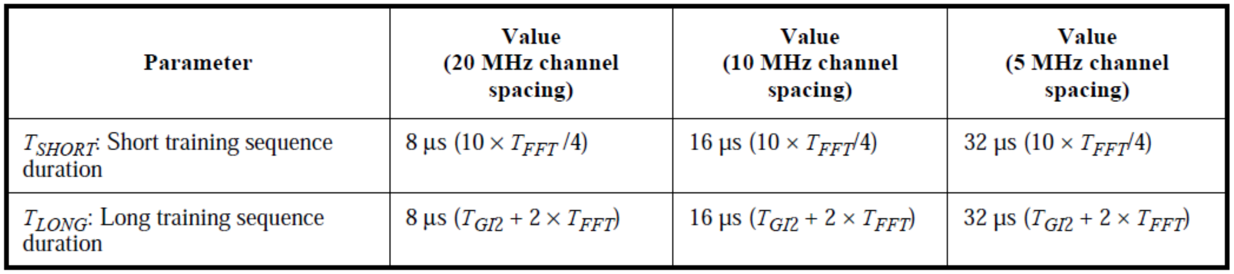
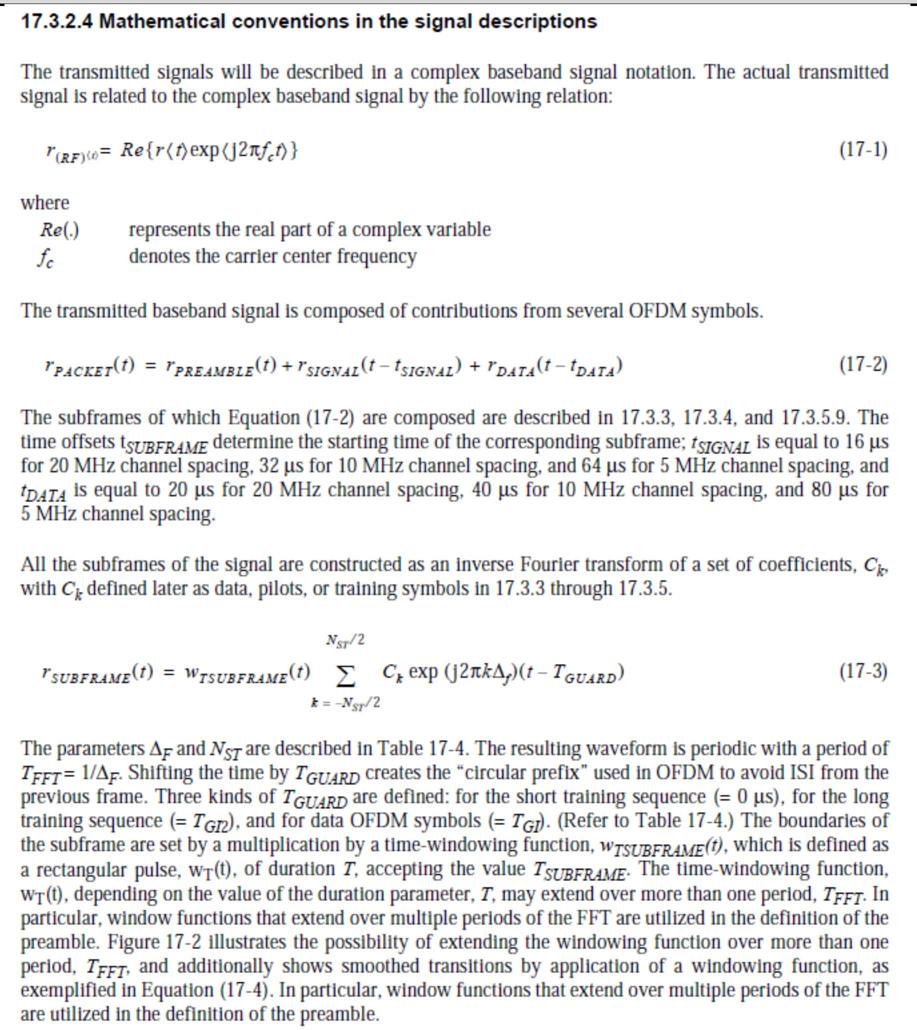
<table>
<tr><th>Claim 23 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \quad (17\text{-}1)$$

where

$Re(.)$ represents the real part of a complex variable
f_c denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

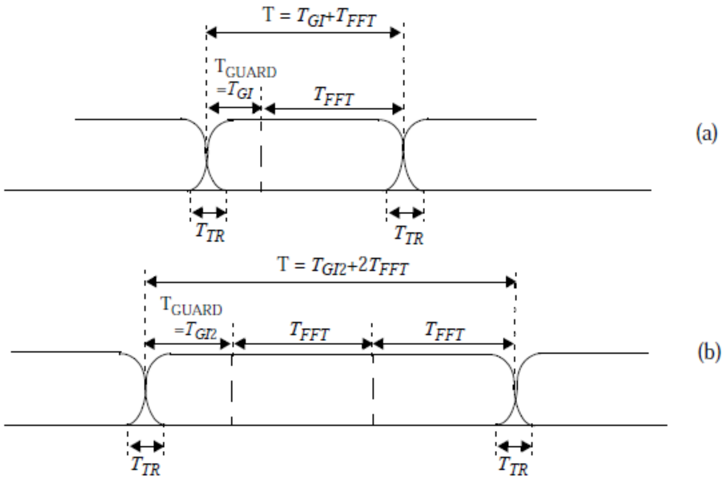
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \quad (17\text{-}2)$$

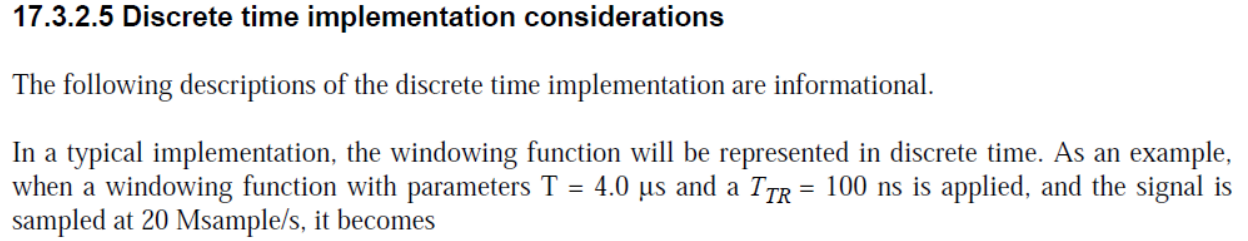
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

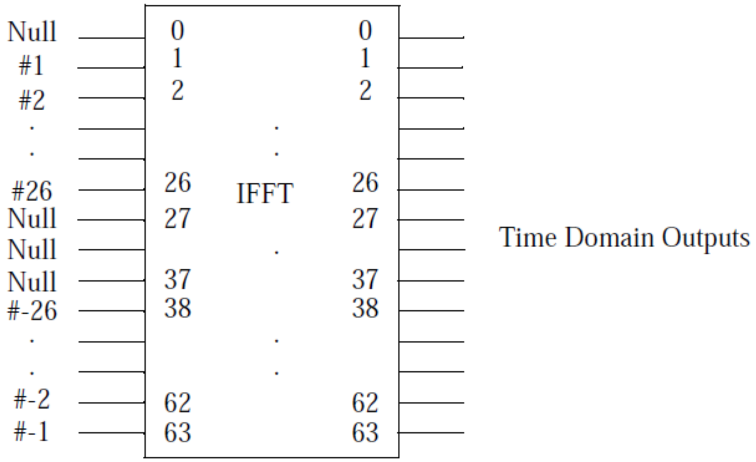
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

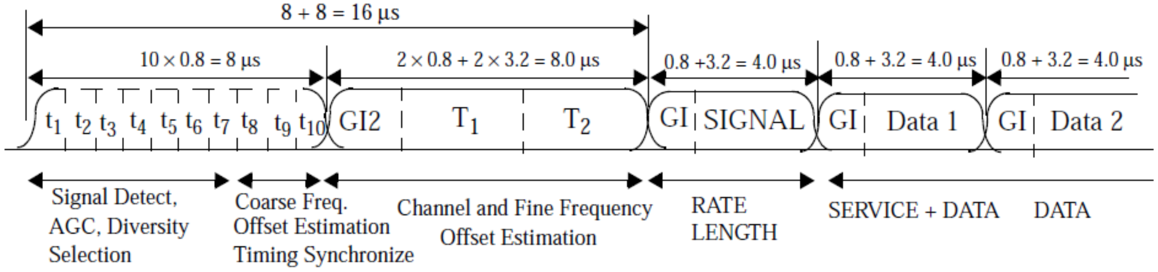
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \quad (17\text{-}3)$$

The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \qquad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 23 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} \qquad (17\text{-}5)$ The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8\ \mu s$. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F(t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6\ \mu s$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8\ \mu s$.

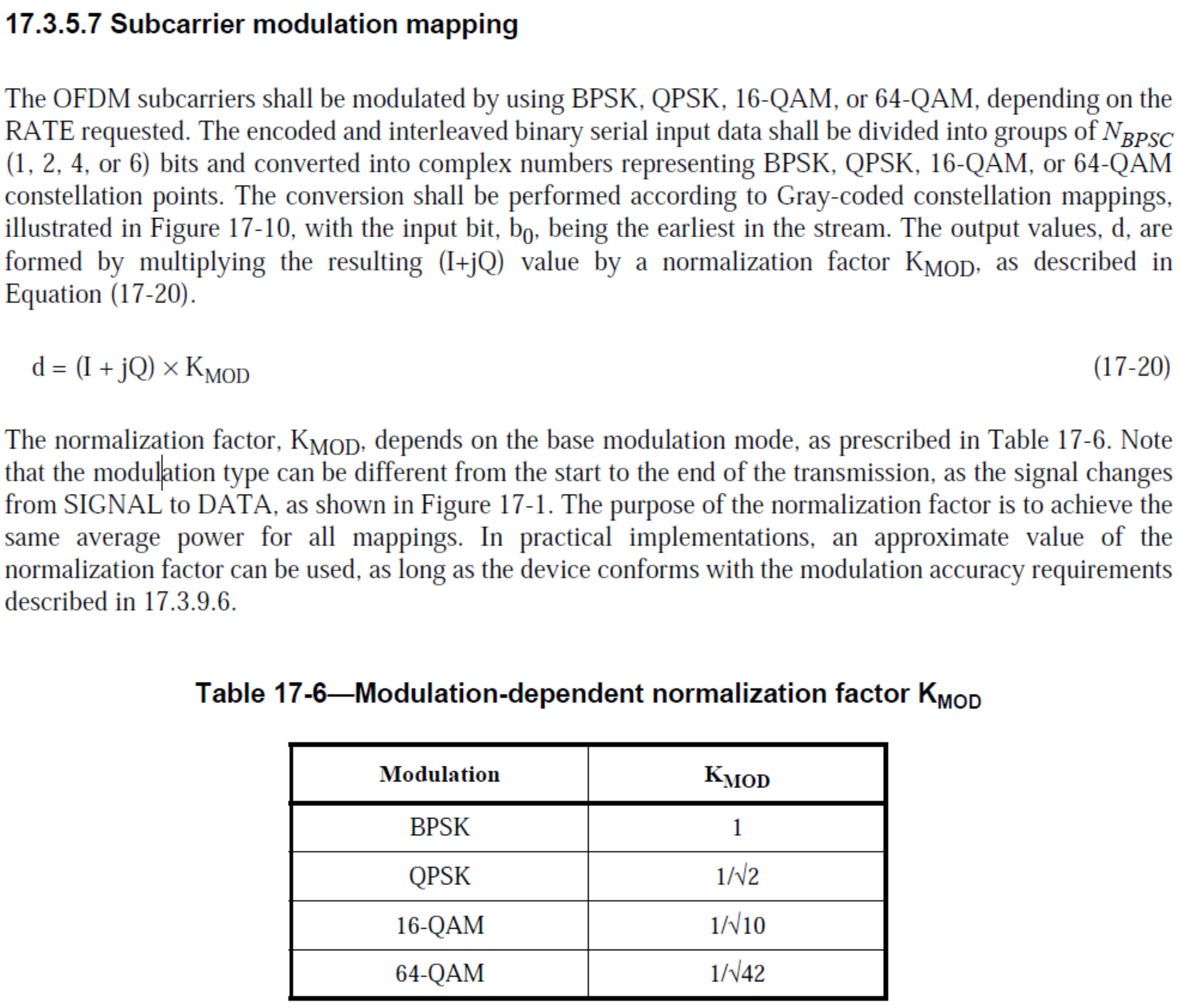
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 23 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7

</td></tr>
</table>

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$P_{-26,26} = \{0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$\begin{aligned} p_{0..126v} = \{&1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ &1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ &-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ &-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \end{aligned} \qquad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

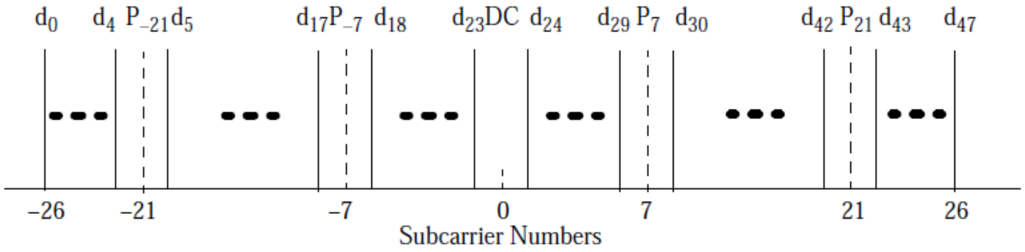


Figure 17-11—Subcarrier frequency allocation

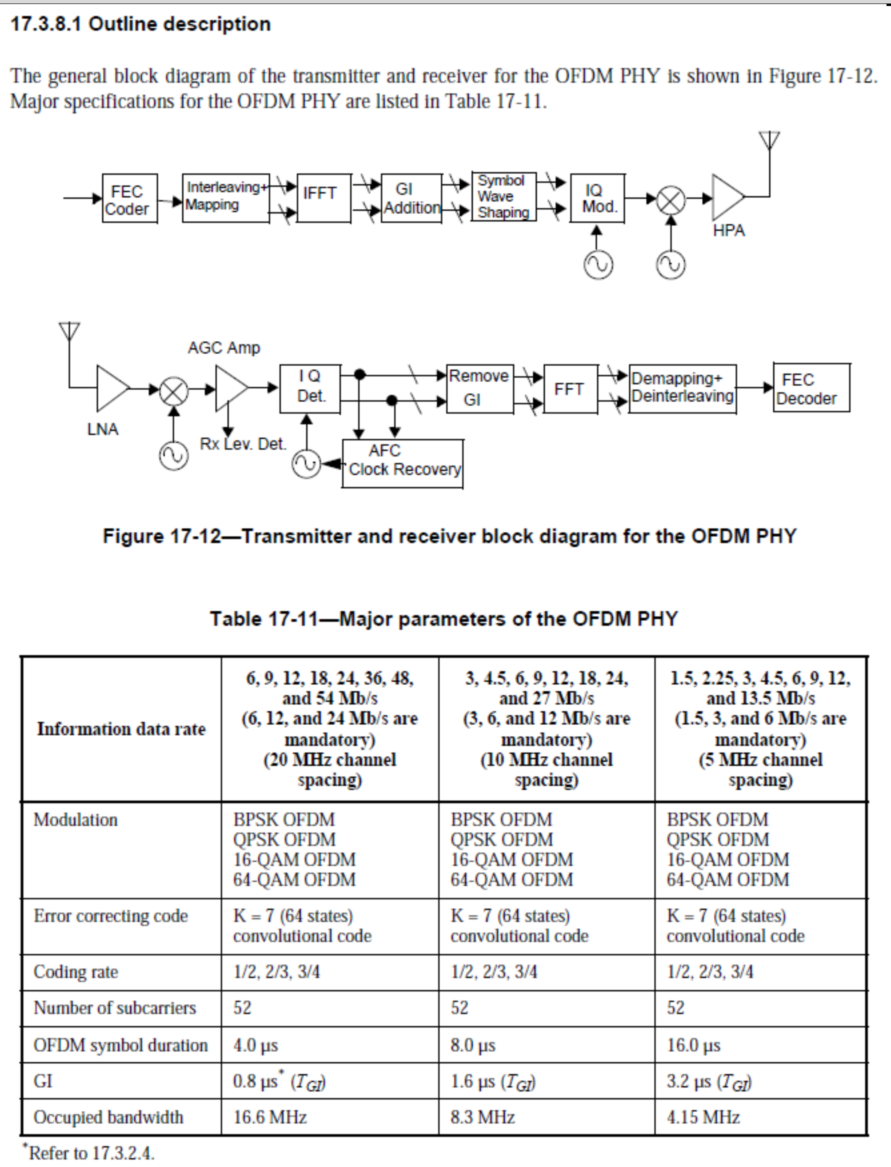
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \qquad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

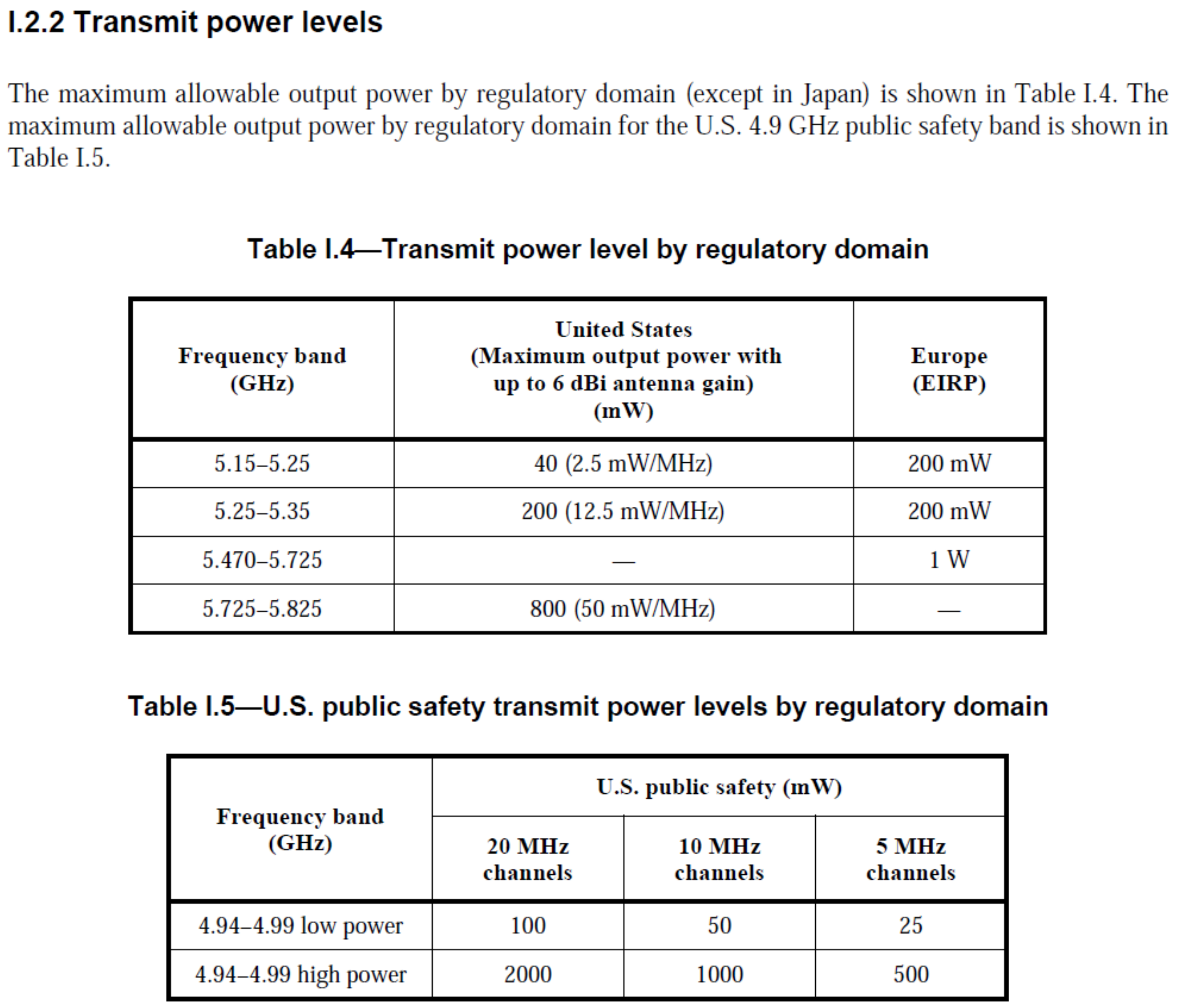
Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

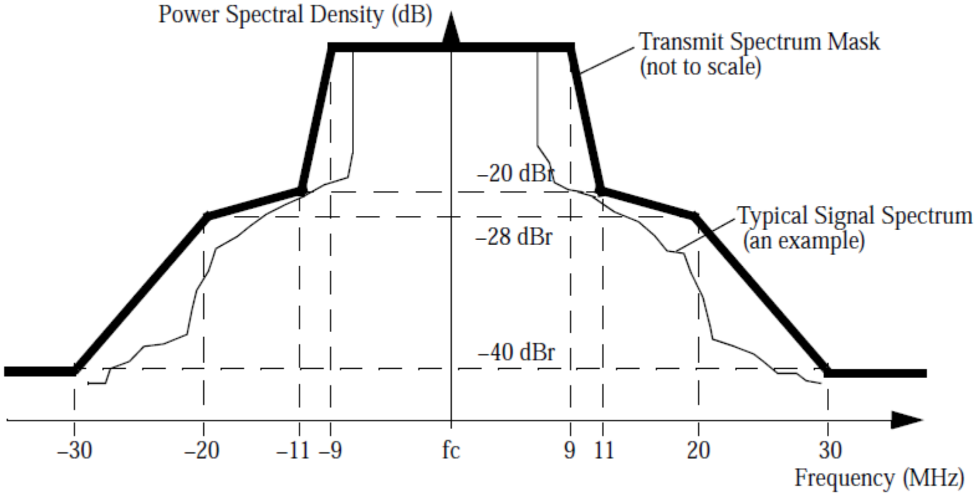
Table I.4—Transmit power level by regulatory domain

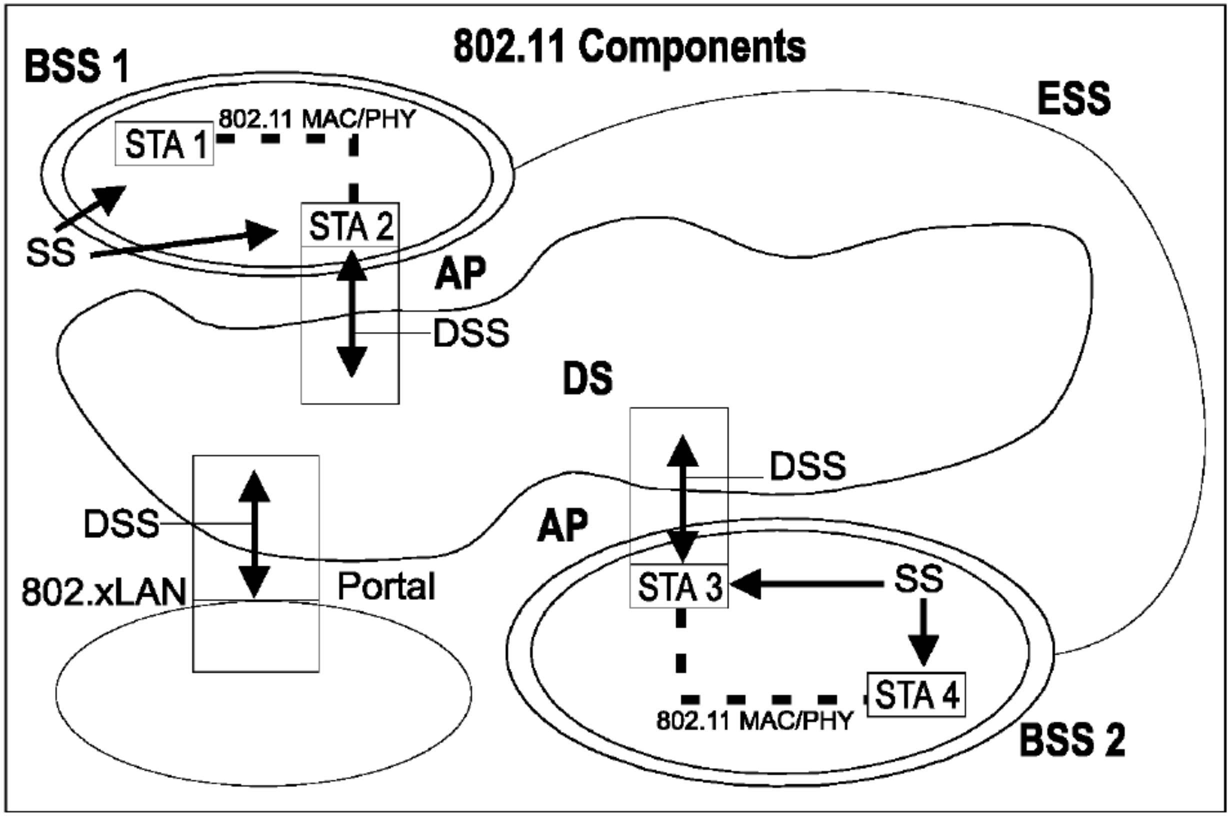
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

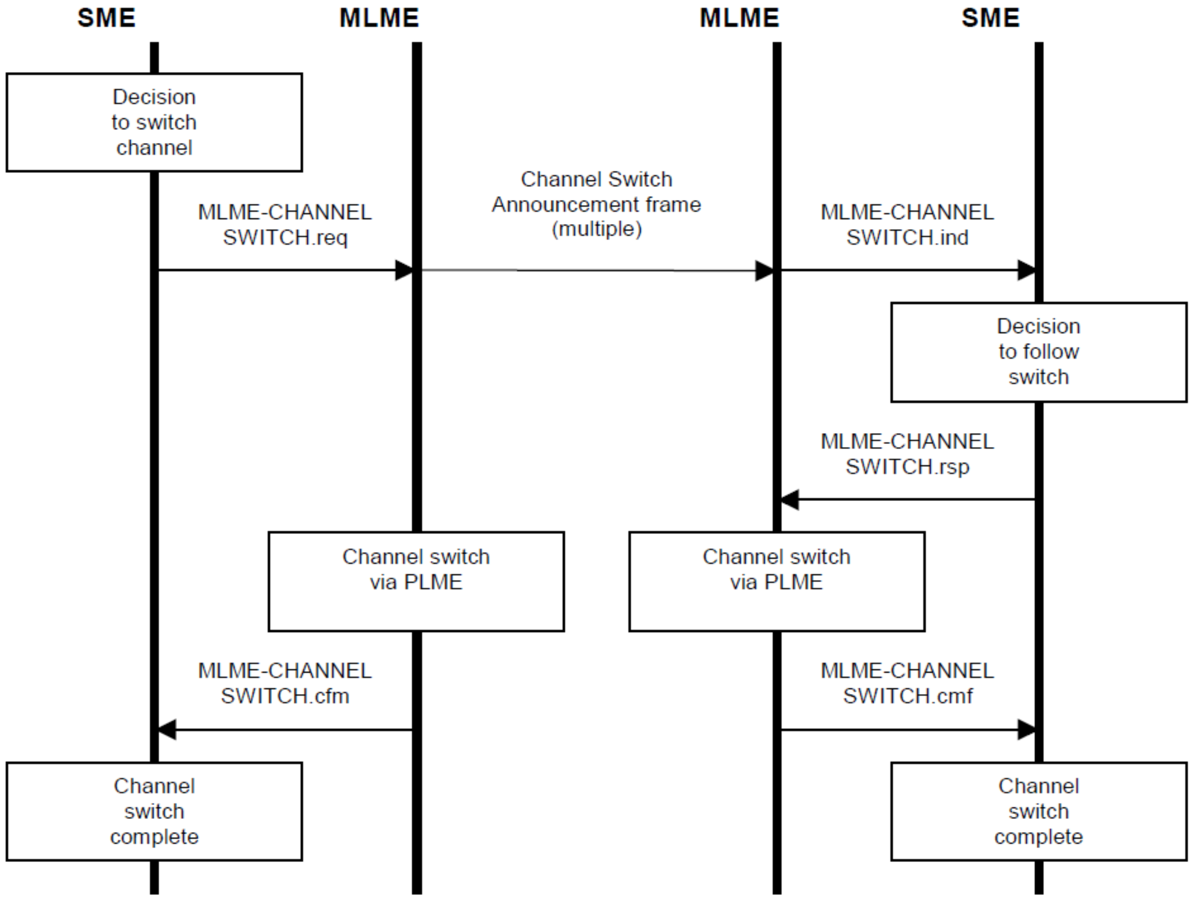
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 23 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

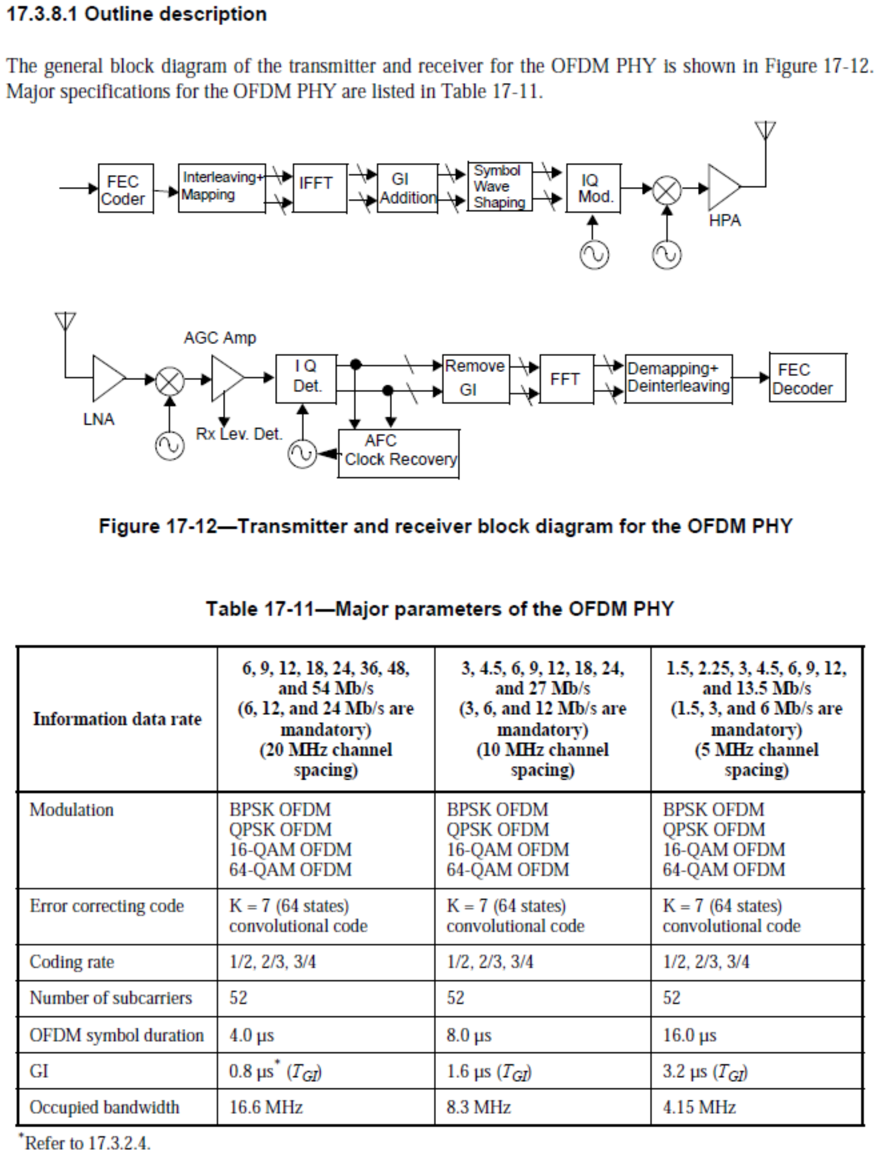
Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 23 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
[24.1] An electronic circuit comprising:	To the extent the preamble is limiting, 802.11-2007 discloses “An electronic circuit comprising.”

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs[*] (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

[*] Refer to 17.3.2.4.

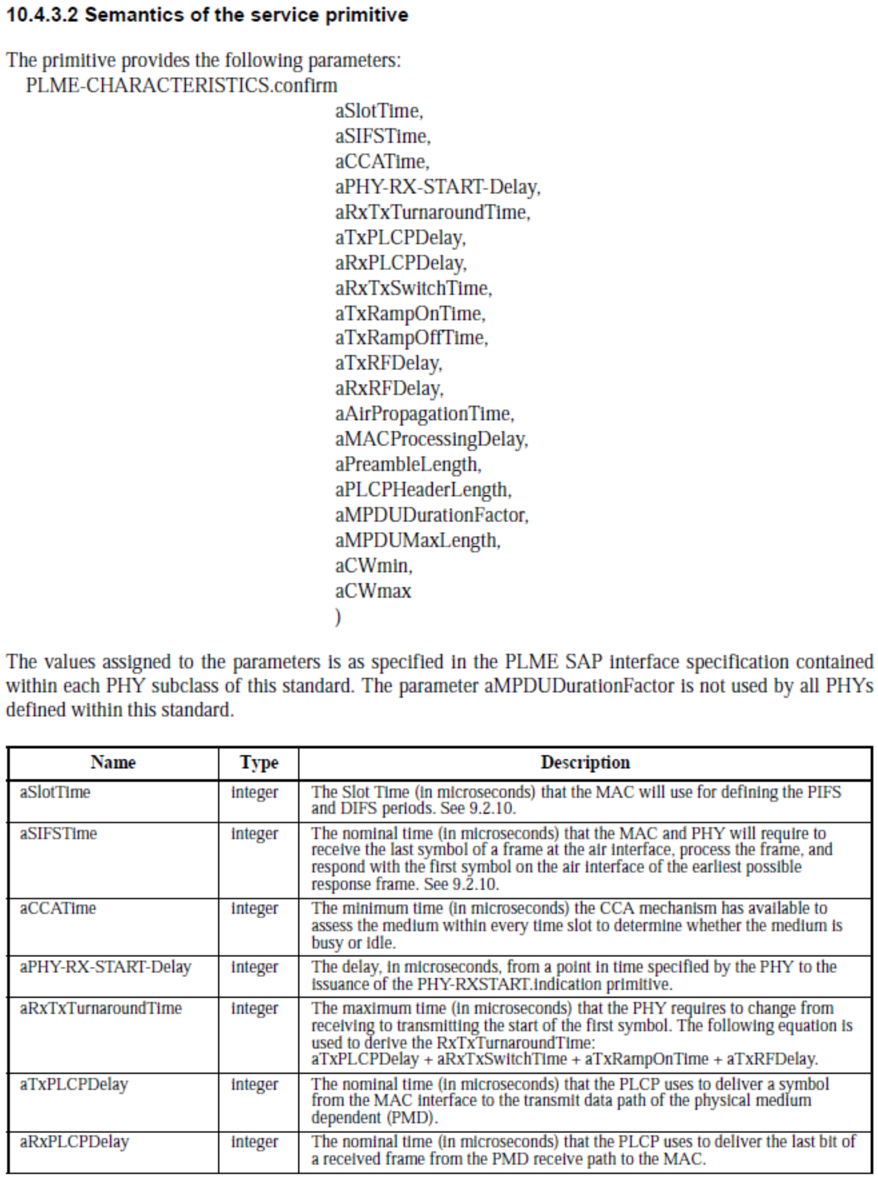
Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[24.2] a first down-converter circuit having a first input coupled to receive a first up-converted signal, a second input coupled to receive a first demodulation signal having a first RF frequency, and an output, wherein the first down-converter circuit outputs a first down-converted signal on the first down-converter output;	802.11-2007 discloses “a first down-converter circuit having a first input coupled to receive a first up-converted signal, a second input coupled to receive a first demodulation signal having a first RF frequency, and an output, wherein the first down-converter circuit outputs a first down-converted signal on the first down-converter output.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

Claim 24 of the ’802 Patent	**Prior Art Reference – 802.11-2007**



10.4.3.2 Semantics of the service primitive

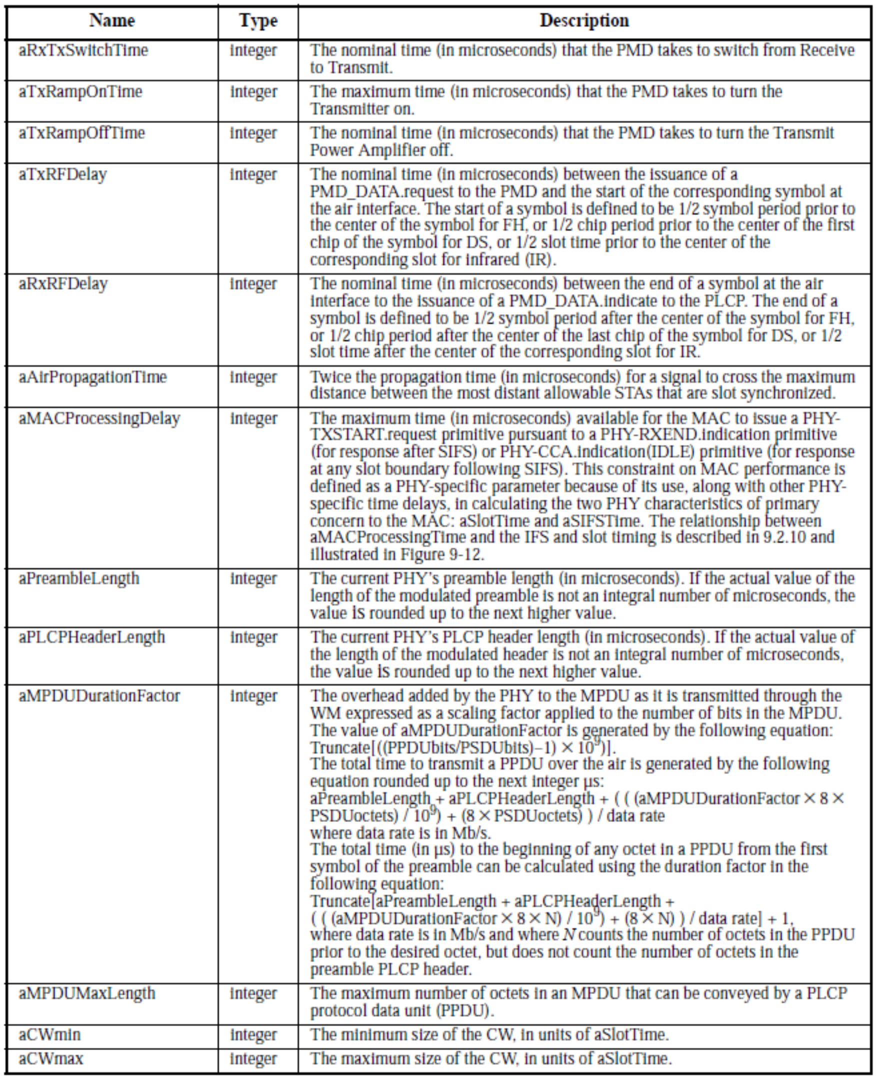
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 24 of the '802 Patent	**Prior Art Reference – 802.11-2007**



Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\mathrm{Truncate}[((\mathrm{PPDUbits}/\mathrm{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times \mathrm{PSDUoctets}) / 10^9) + (8 \times \mathrm{PSDUoctets})) / \mathrm{data\ rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\mathrm{Truncate}[\mathrm{aPreambleLength} + \mathrm{aPLCPHeaderLength} + (((\mathrm{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \mathrm{data\ rate}] + 1$, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

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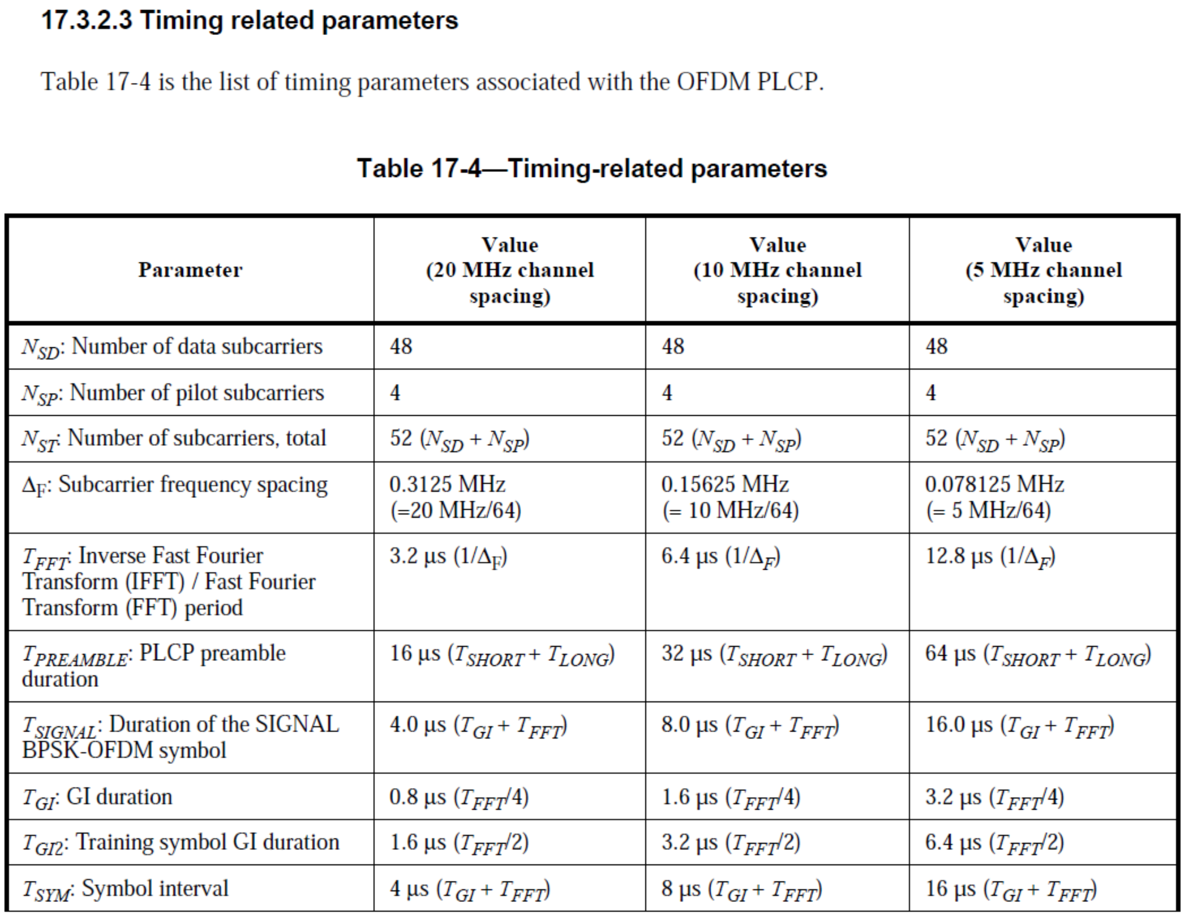
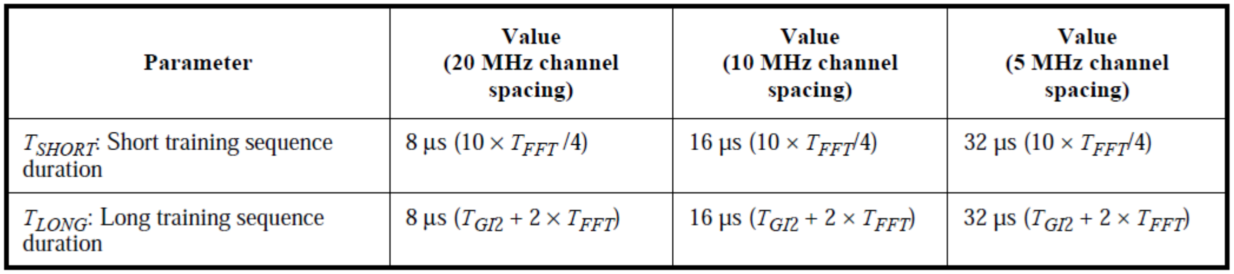
	

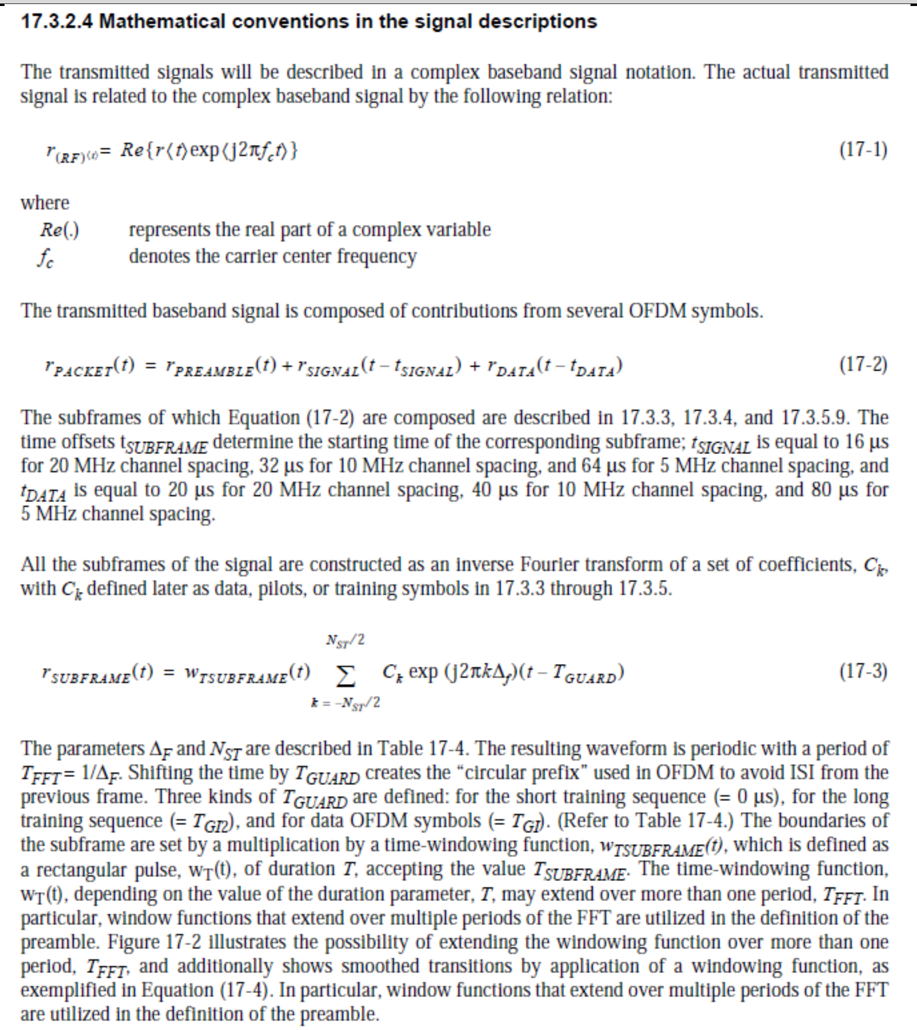
17.3.2.3 Timing related parameters

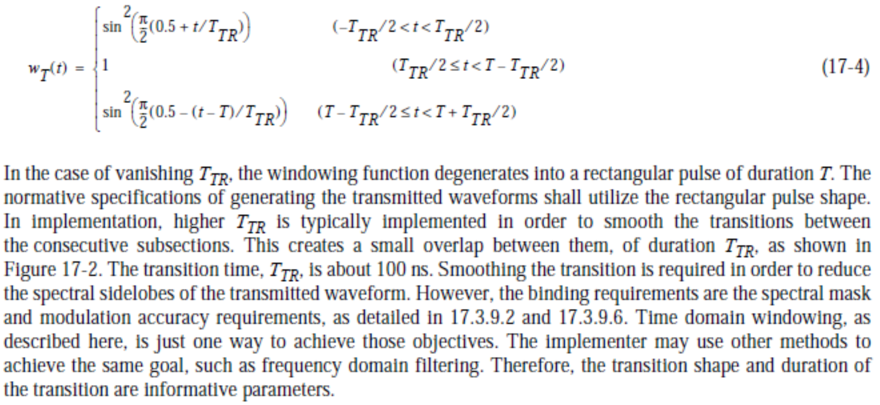
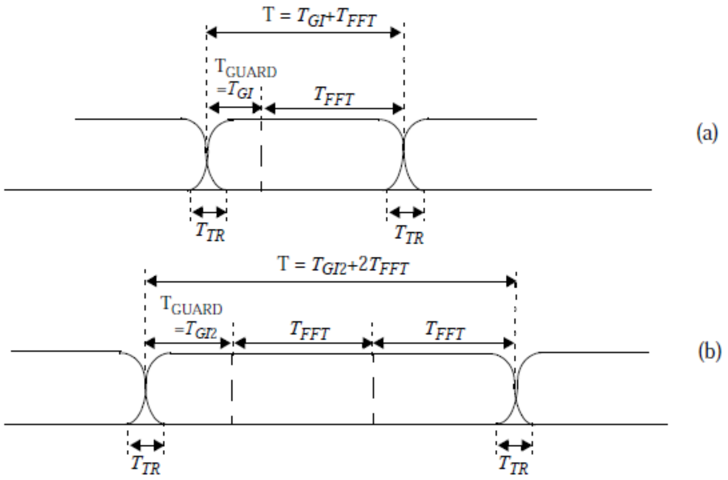
Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

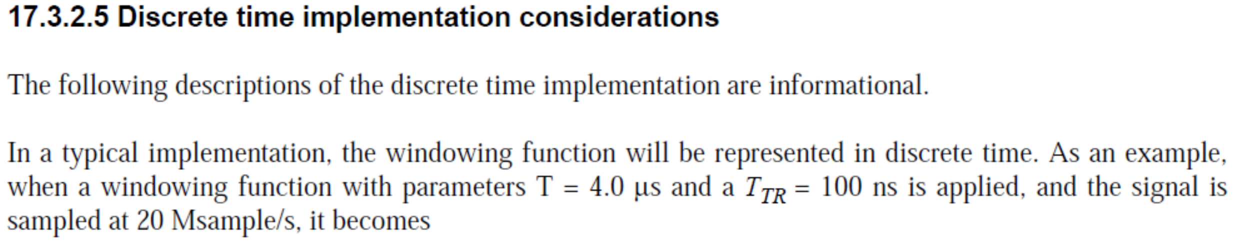
Table 17-4—Timing-related parameters

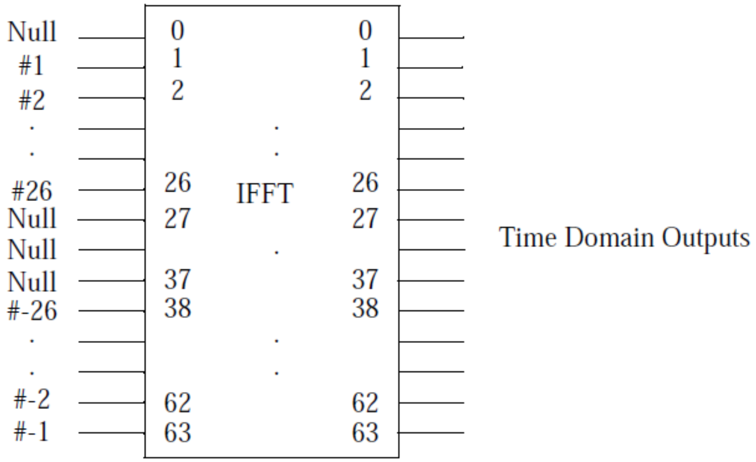
Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)	6.4 μs ($1/\Delta_F$)	12.8 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)	32 μs ($T_{SHORT} + T_{LONG}$)	64 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)	8.0 μs ($T_{GI} + T_{FFT}$)	16.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)	1.6 μs ($T_{FFT}/4$)	3.2 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)	3.2 μs ($T_{FFT}/2$)	6.4 μs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)	8 μs ($T_{GI} + T_{FFT}$)	16 μs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 μs (10 × T_{FFT} /4)</td><td>16 μs (10 × T_{FFT}/4)</td><td>32 μs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 μs (T_{GI2} + 2 × T_{FFT})</td><td>16 μs (T_{GI2} + 2 × T_{FFT})</td><td>32 μs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.4 Mathematical conventions in the signal descriptions** The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation: $r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1) where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency The transmitted baseband signal is composed of contributions from several OFDM symbols. $r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA})$ (17-2) The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing. All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5. $r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD})$ (17-3) The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \quad (17\text{-}5)$$ The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

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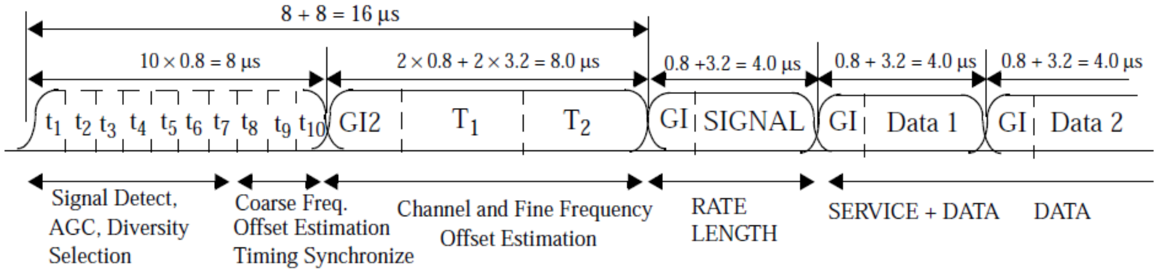
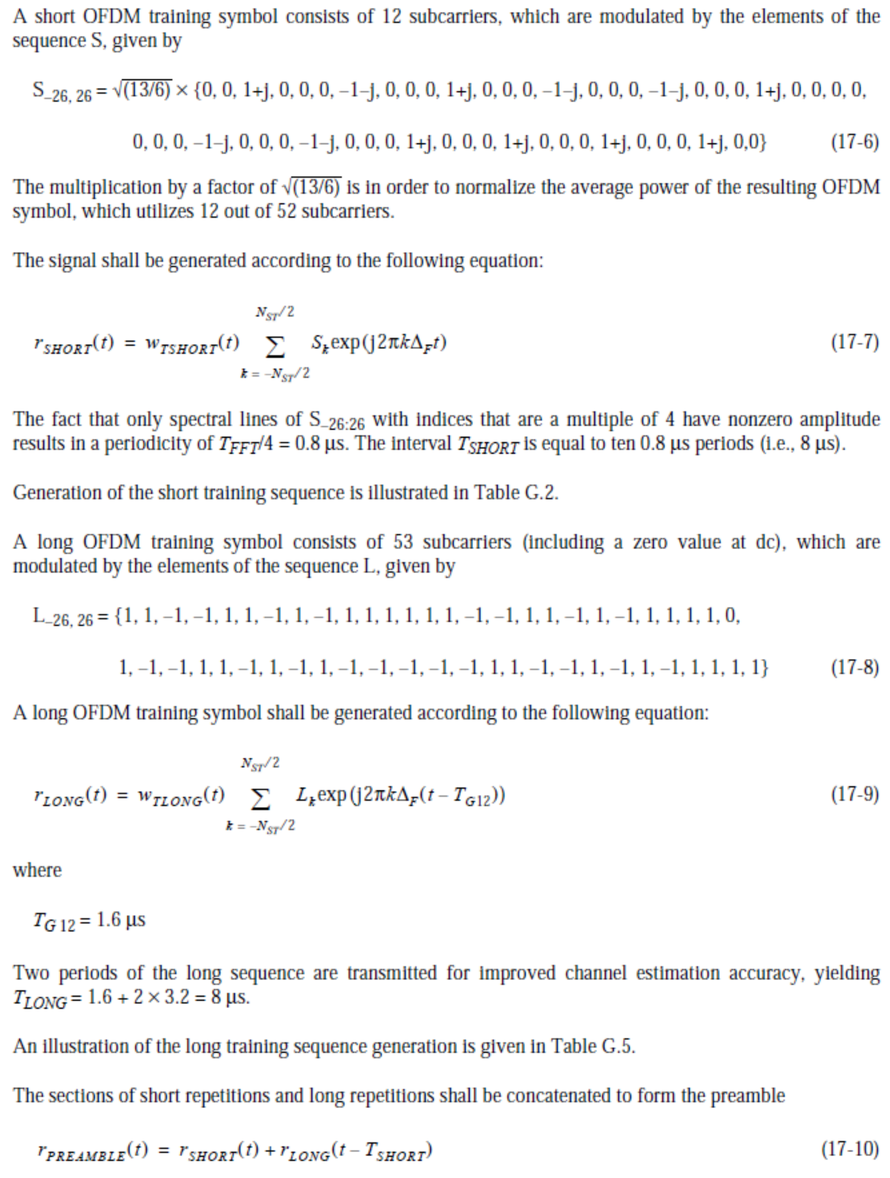
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

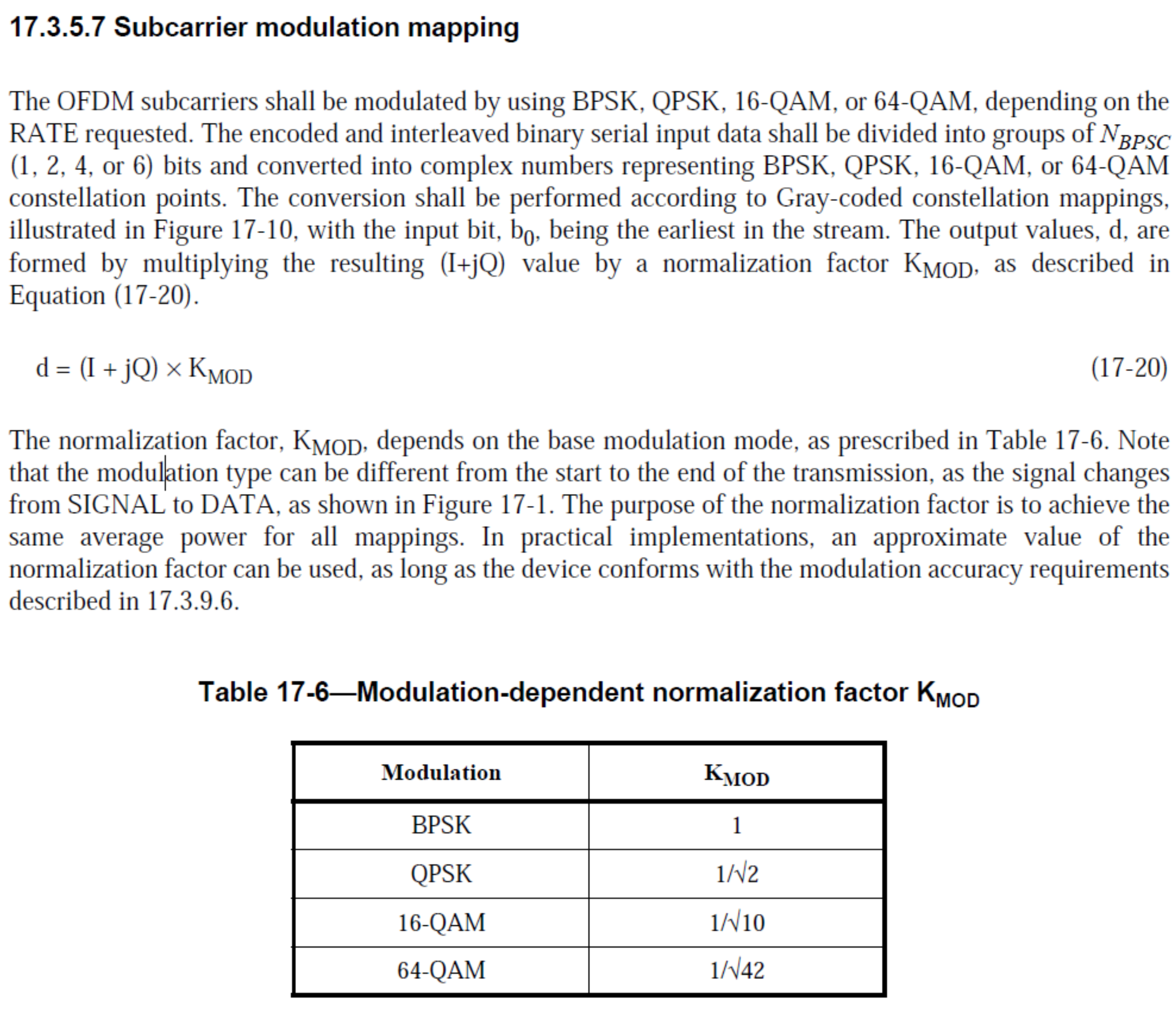
An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

Claim 24 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See excerpt below



17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

Modulation	**K_{MOD}**
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

See, e.g., 802.11-2007 § 17.3.5.7

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	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k \exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,$$
$$1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,$$
$$-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,$$
$$-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

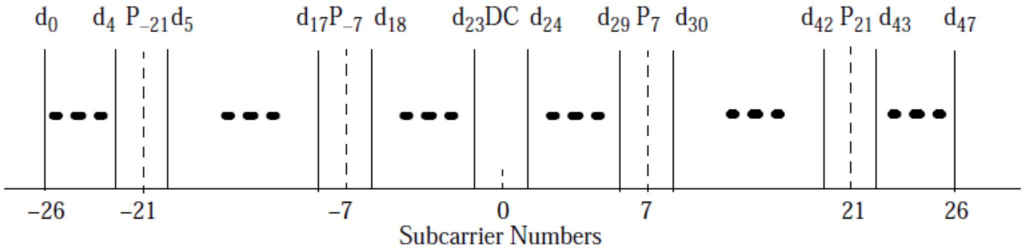


Figure 17-11—Subcarrier frequency allocation

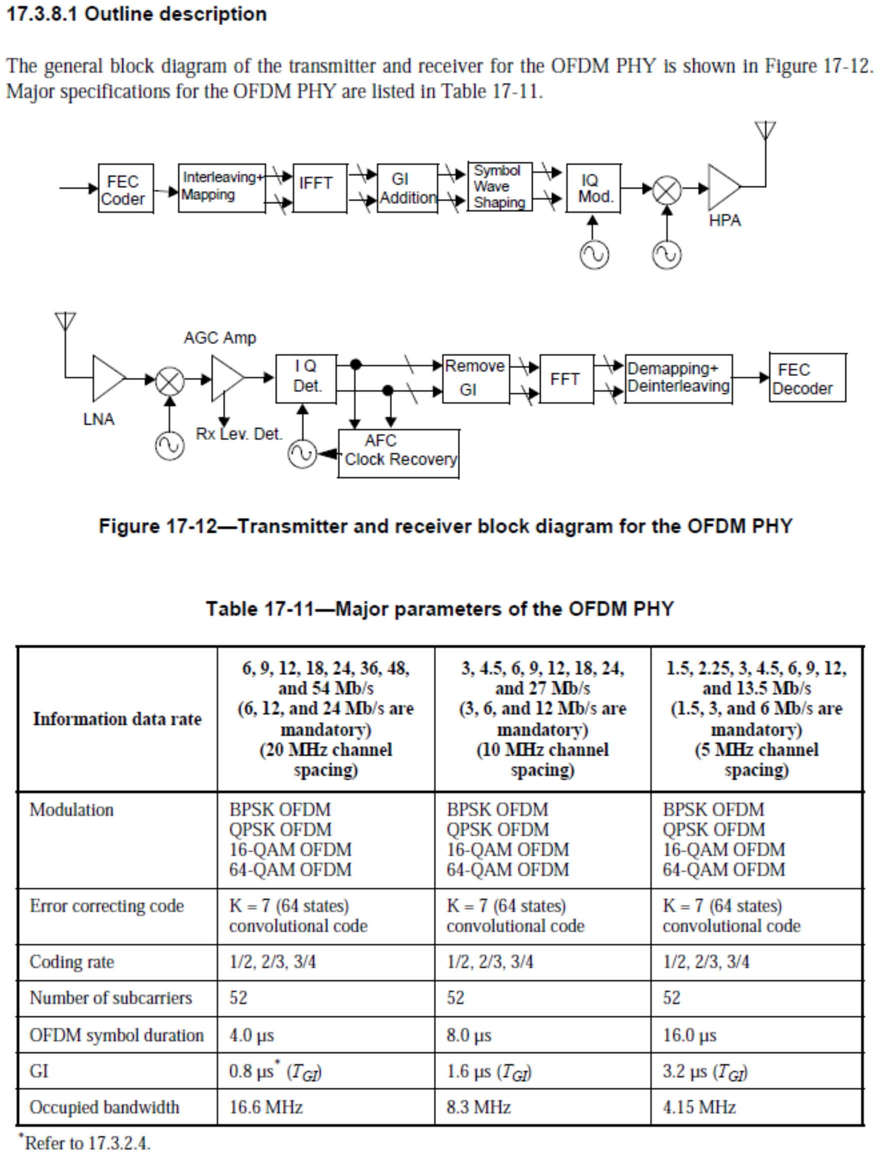
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 24 of the '802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

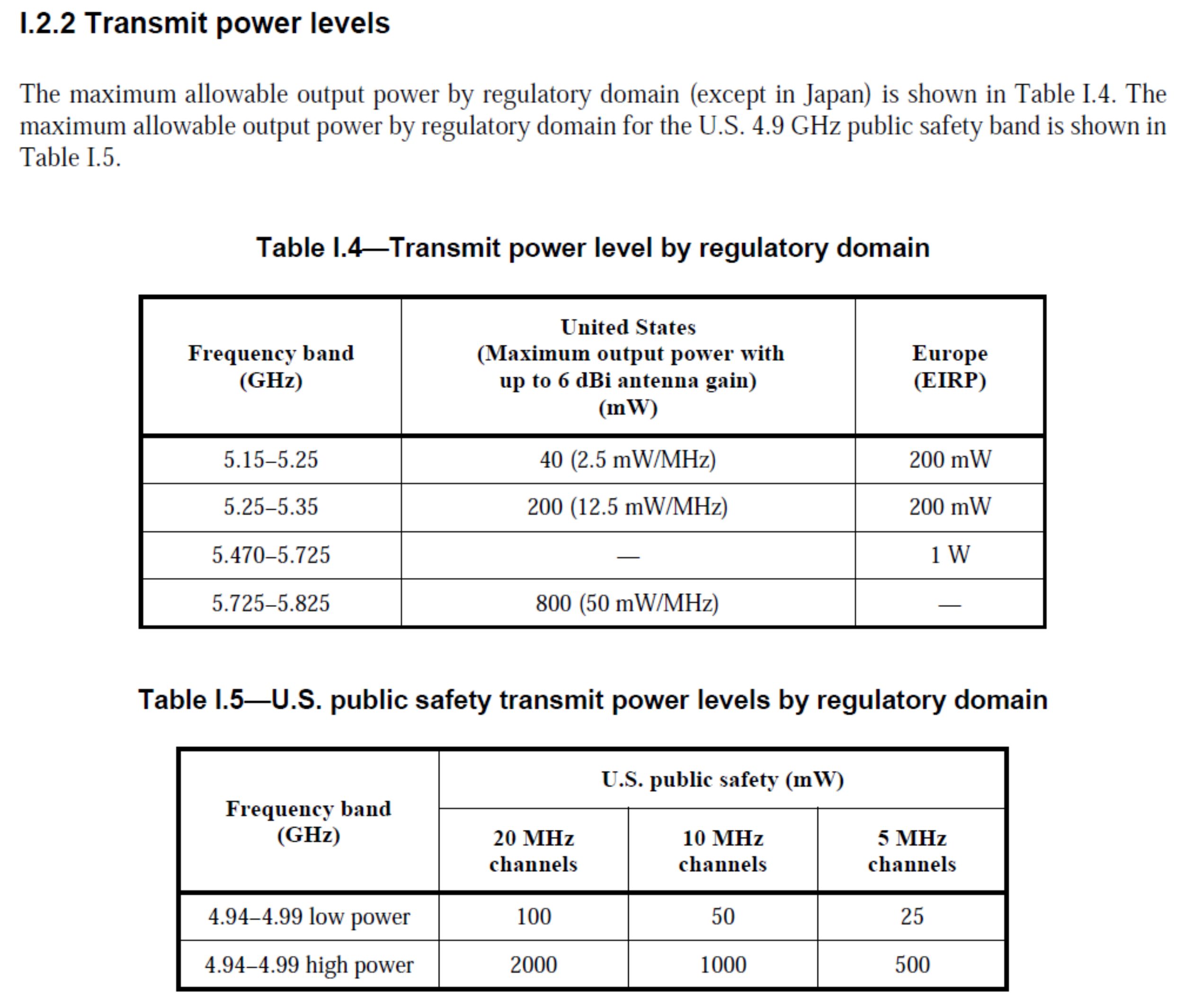
Table 17-11—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007



I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

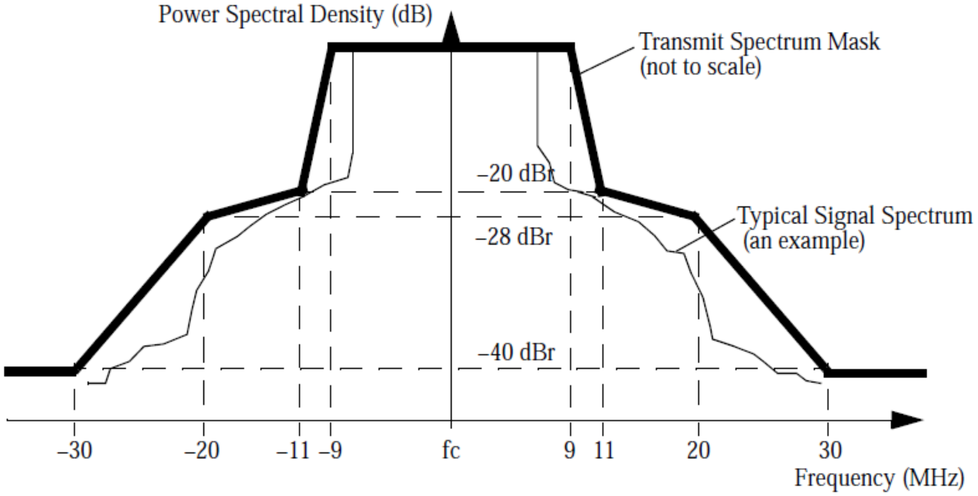
Table I.4—Transmit power level by regulatory domain

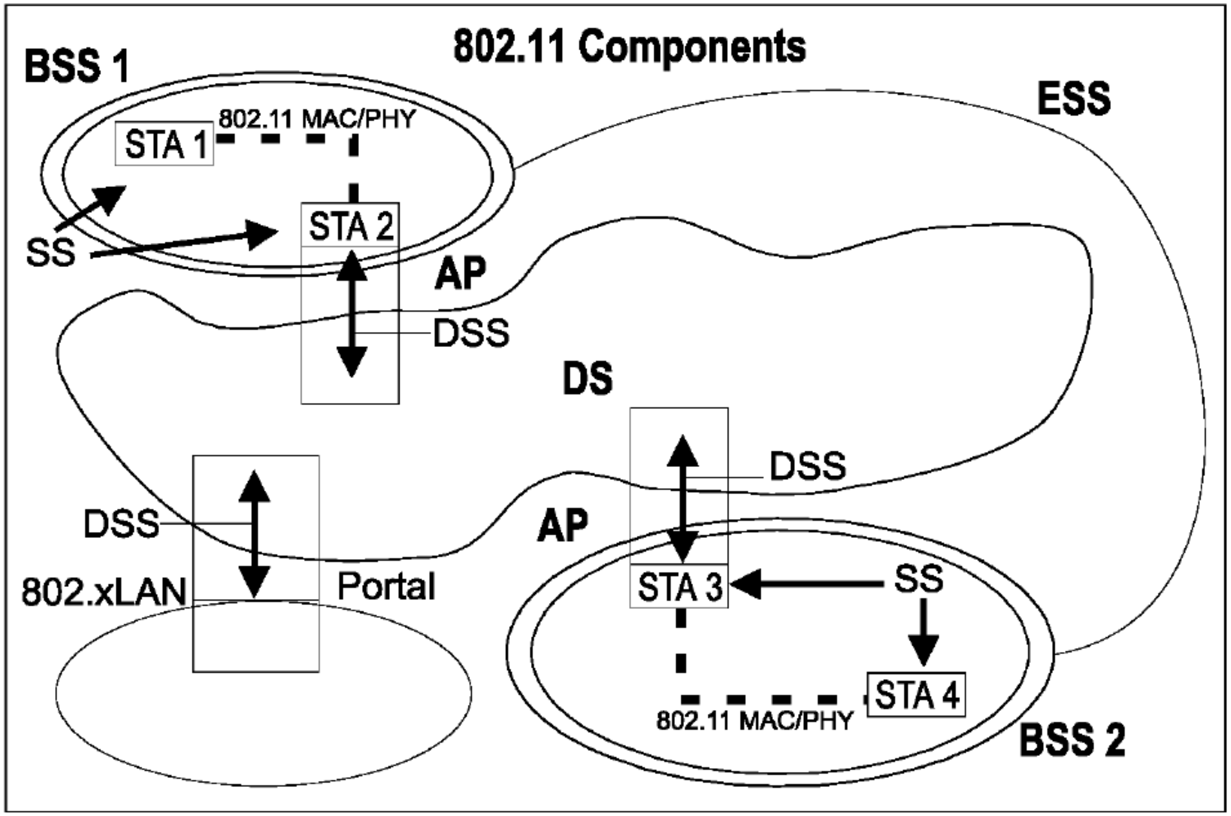
Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	200 mW
5.25–5.35	200 (12.5 mW/MHz)	200 mW
5.470–5.725	—	1 W
5.725–5.825	800 (50 mW/MHz)	—

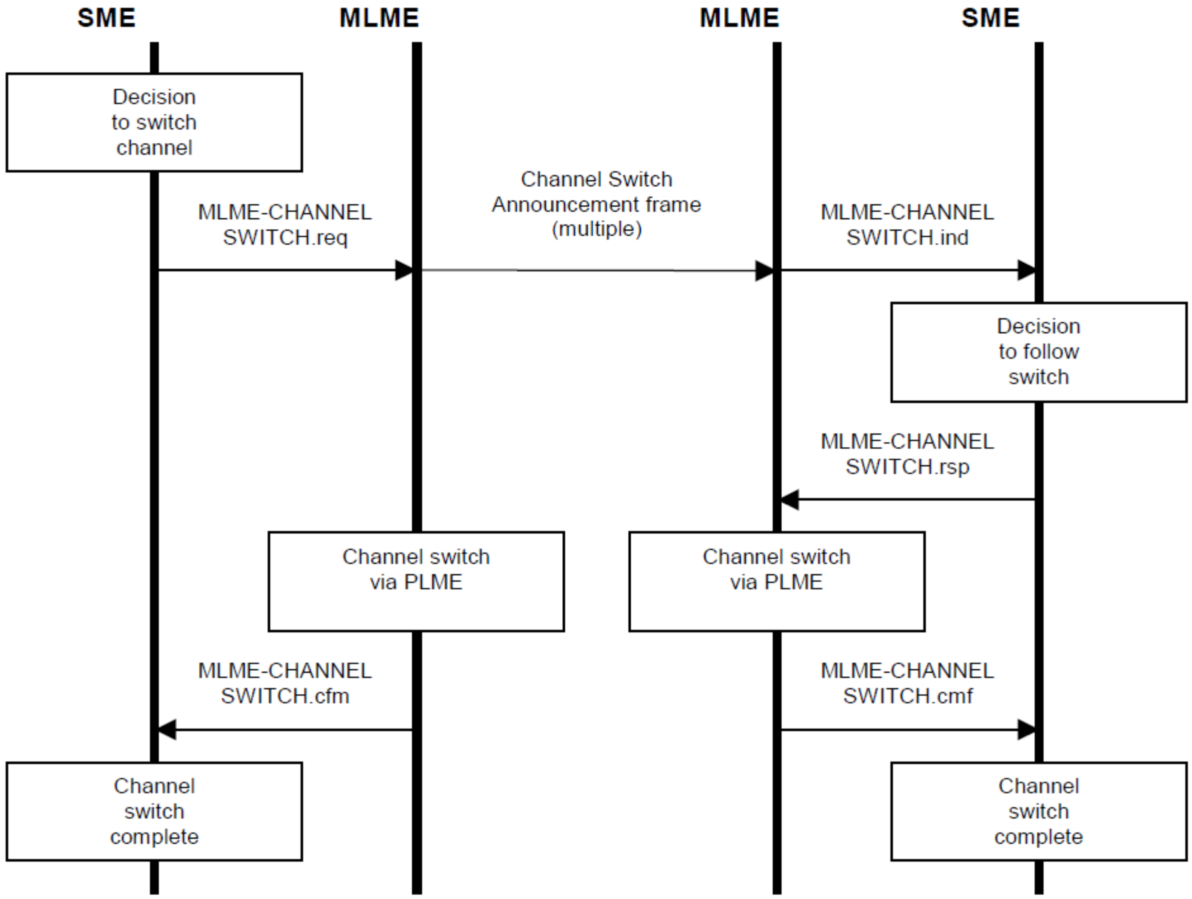
Table I.5—U.S. public safety transmit power levels by regulatory domain

Frequency band (GHz)	U.S. public safety (mW)		
	20 MHz channels	10 MHz channels	5 MHz channels
4.94–4.99 low power	100	50	25
4.94–4.99 high power	2000	1000	500

See, e.g., 802.11-2007 § I.2.2

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[24.3] a second down-converter circuit having a first input coupled to receive the first up-converted signal, a second input coupled to receive a second demodulation signal having a second RF frequency different than the first RF frequency, and an output, wherein the second down-converter outputs a second down-converted signal on the second down-converter output, wherein the first up-converted signal comprises a first signal modulated at the first RF frequency and a second signal modulated at the second RF frequency; and	802.11-2007 discloses "a second down-converter circuit having a first input coupled to receive the first up-converted signal, a second input coupled to receive a second demodulation signal having a second RF frequency different than the first RF frequency, and an output, wherein the second down-converter outputs a second down-converted signal on the second down-converter output, wherein the first up-converted signal comprises a first signal modulated at the first RF frequency and a second signal modulated at the second RF frequency." See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks

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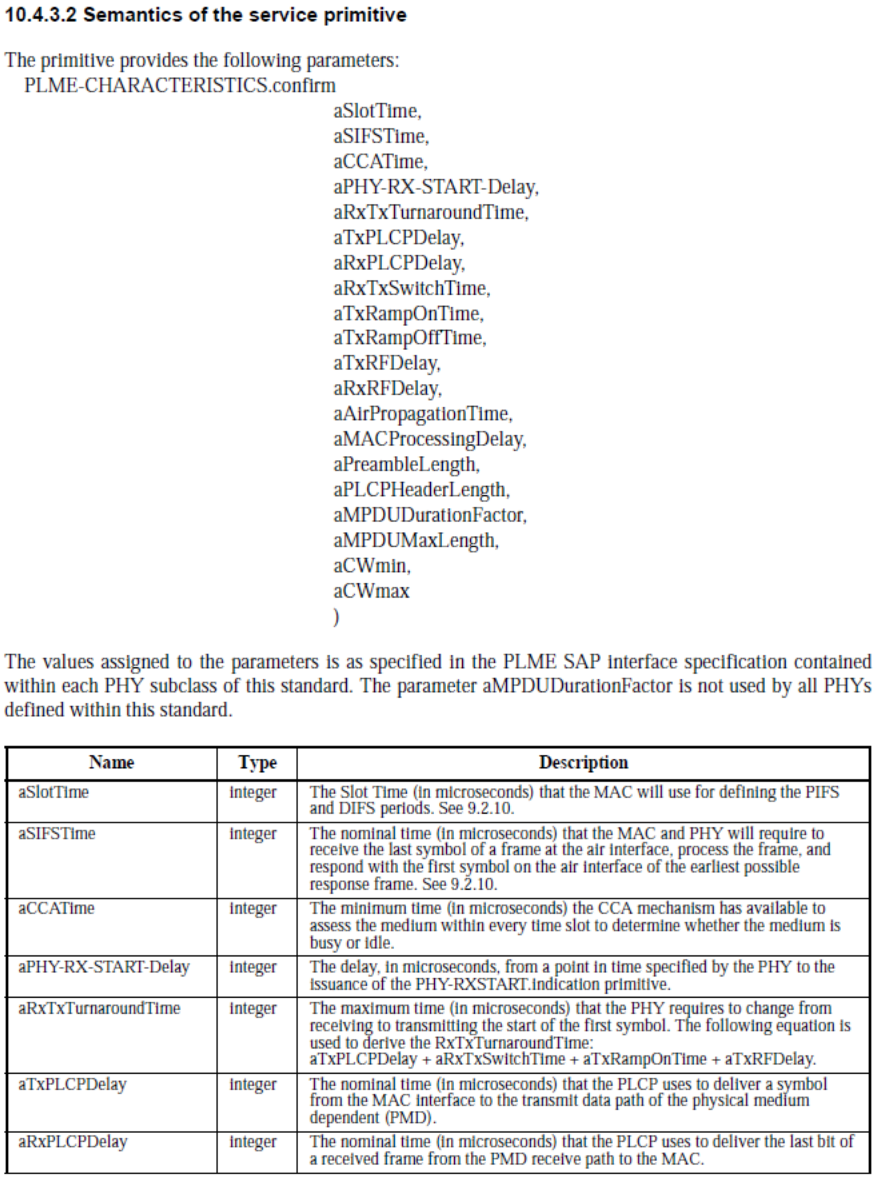
	this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS. IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC**

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement. The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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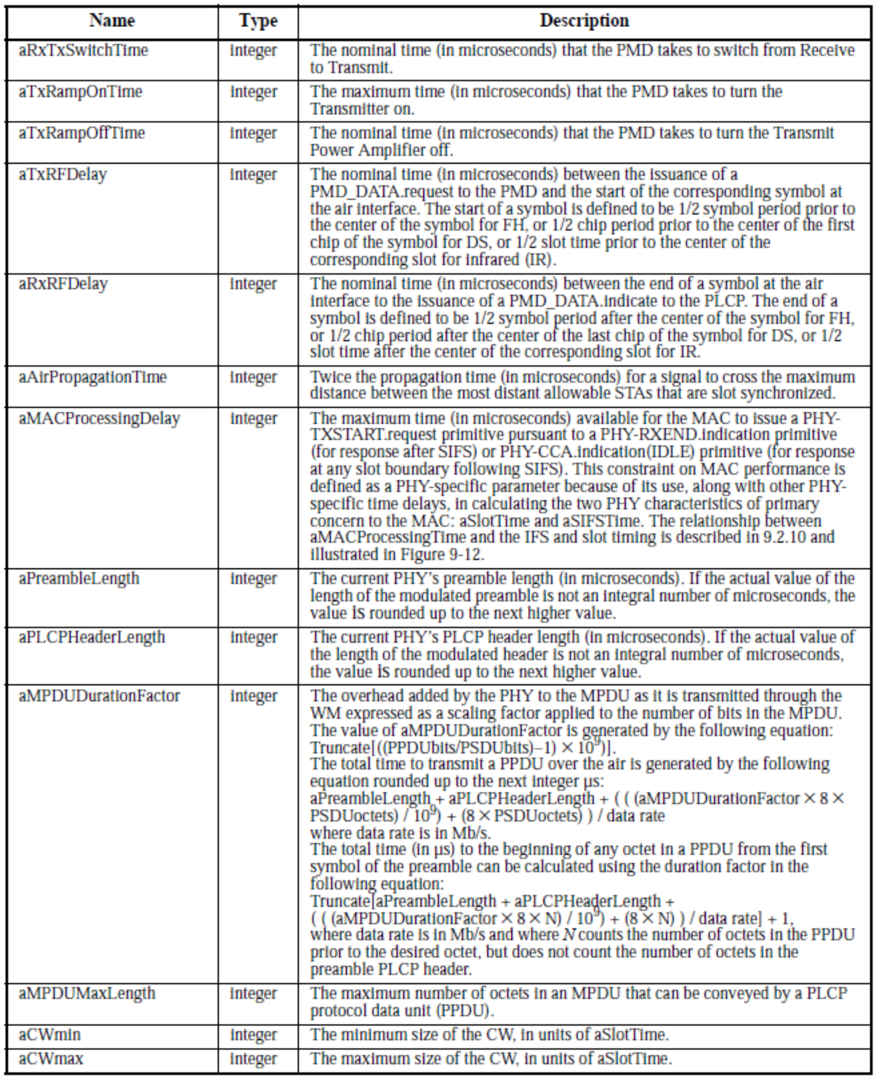
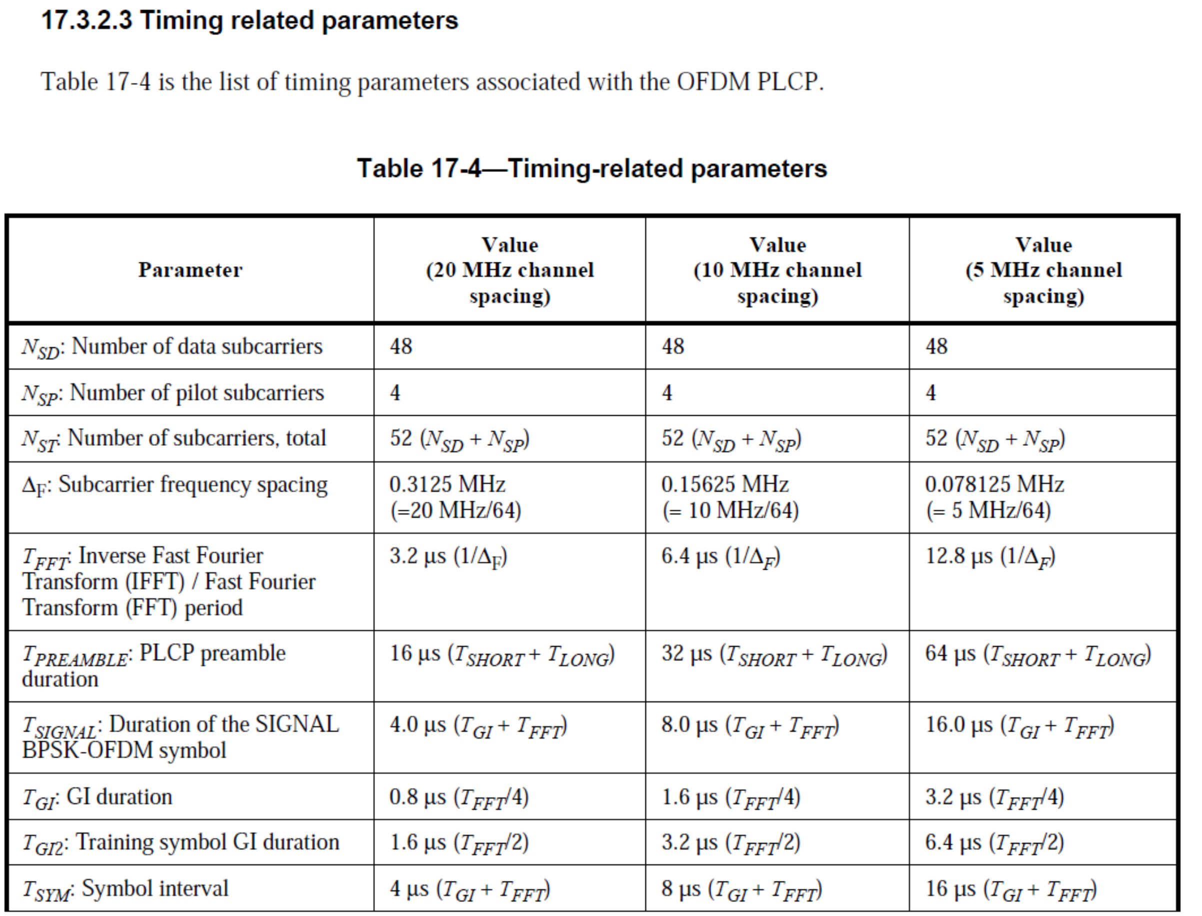


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[((\text{PPDUbits}/\text{PSDUbits})-1) \times 10^9)]$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: $\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets})) / \text{data rate}$ where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + (((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N)) / \text{data rate}] + 1$, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

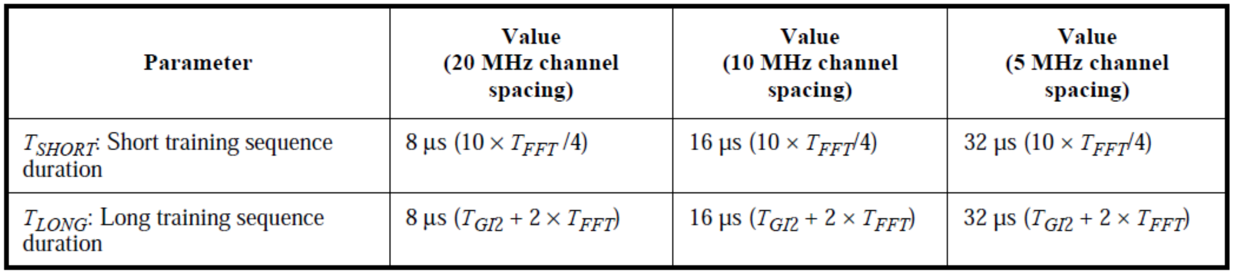
<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


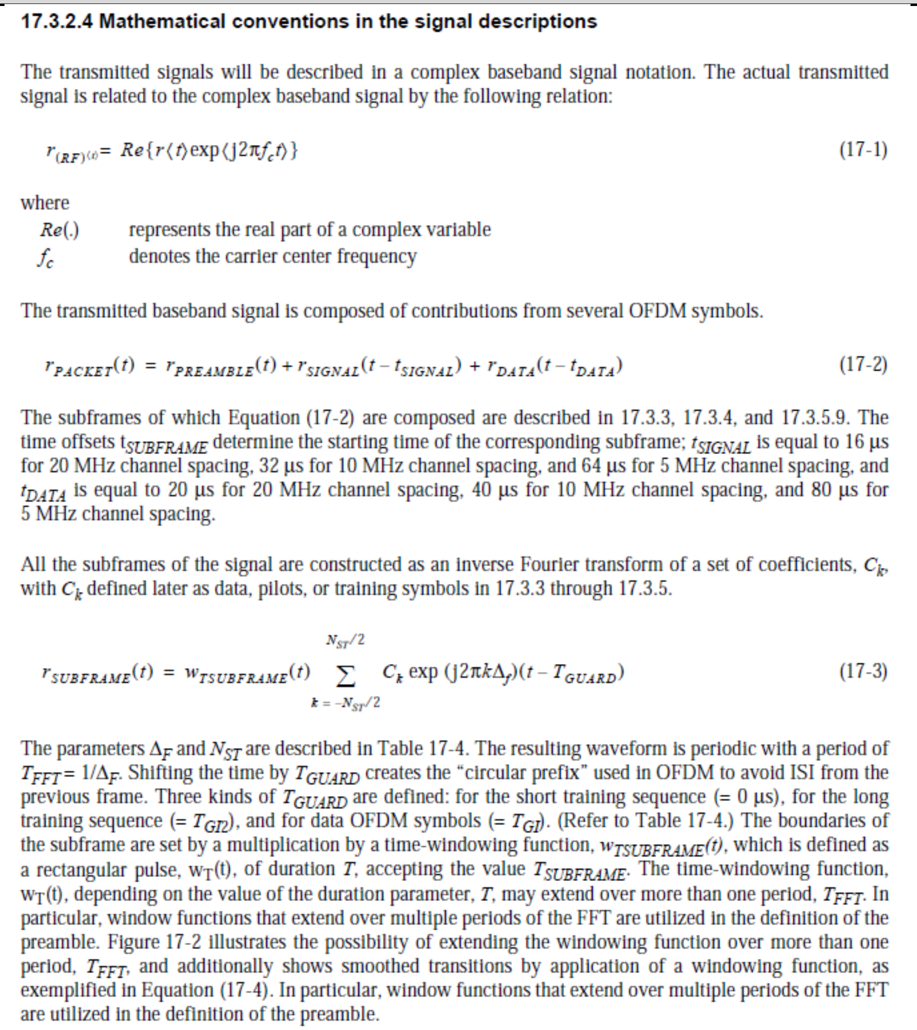
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>N_{SD}: Number of data subcarriers</td><td>48</td><td>48</td><td>48</td></tr>
<tr><td>N_{SP}: Number of pilot subcarriers</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>N_{ST}: Number of subcarriers, total</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td><td>52 ($N_{SD} + N_{SP}$)</td></tr>
<tr><td>Δ_F: Subcarrier frequency spacing</td><td>0.3125 MHz
(=20 MHz/64)</td><td>0.15625 MHz
(= 10 MHz/64)</td><td>0.078125 MHz
(= 5 MHz/64)</td></tr>
<tr><td>T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period</td><td>3.2 μs ($1/\Delta_F$)</td><td>6.4 μs ($1/\Delta_F$)</td><td>12.8 μs ($1/\Delta_F$)</td></tr>
<tr><td>$T_{PREAMBLE}$: PLCP preamble duration</td><td>16 μs ($T_{SHORT} + T_{LONG}$)</td><td>32 μs ($T_{SHORT} + T_{LONG}$)</td><td>64 μs ($T_{SHORT} + T_{LONG}$)</td></tr>
<tr><td>T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol</td><td>4.0 μs ($T_{GI} + T_{FFT}$)</td><td>8.0 μs ($T_{GI} + T_{FFT}$)</td><td>16.0 μs ($T_{GI} + T_{FFT}$)</td></tr>
<tr><td>T_{GI}: GI duration</td><td>0.8 μs ($T_{FFT}/4$)</td><td>1.6 μs ($T_{FFT}/4$)</td><td>3.2 μs ($T_{FFT}/4$)</td></tr>
<tr><td>T_{GI2}: Training symbol GI duration</td><td>1.6 μs ($T_{FFT}/2$)</td><td>3.2 μs ($T_{FFT}/2$)</td><td>6.4 μs ($T_{FFT}/2$)</td></tr>
<tr><td>T_{SYM}: Symbol interval</td><td>4 μs ($T_{GI} + T_{FFT}$)</td><td>8 μs ($T_{GI} + T_{FFT}$)</td><td>16 μs ($T_{GI} + T_{FFT}$)</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value (20 MHz channel spacing)</th><th>Value (10 MHz channel spacing)</th><th>Value (5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \qquad (17\text{-}1)$$

where

$Re(.)$	represents the real part of a complex variable
f_c	denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

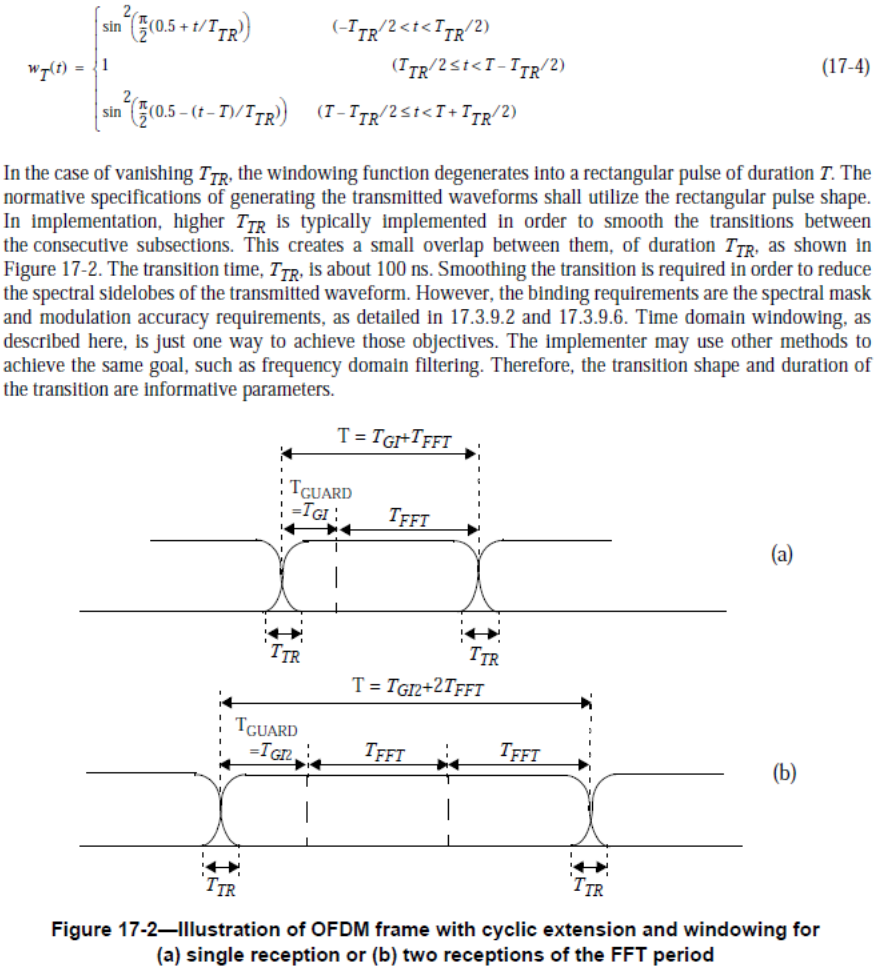
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

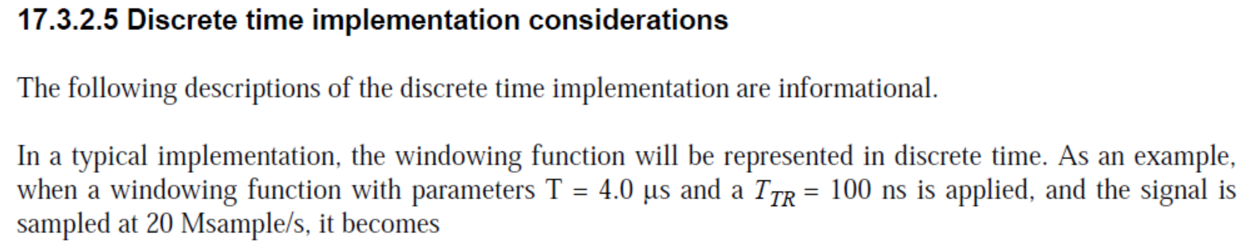
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

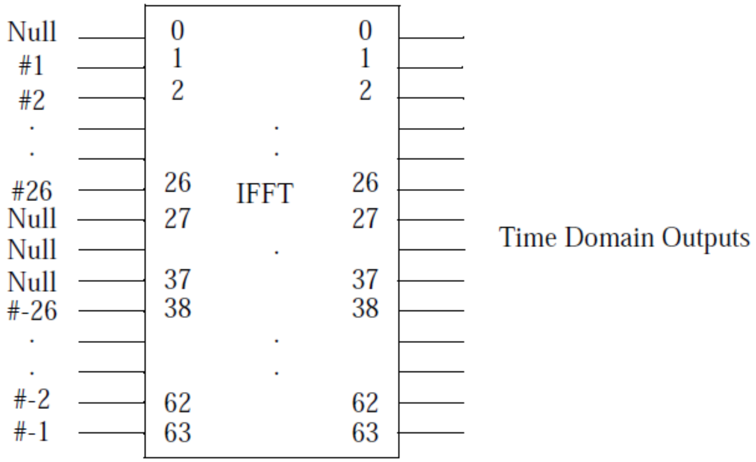
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

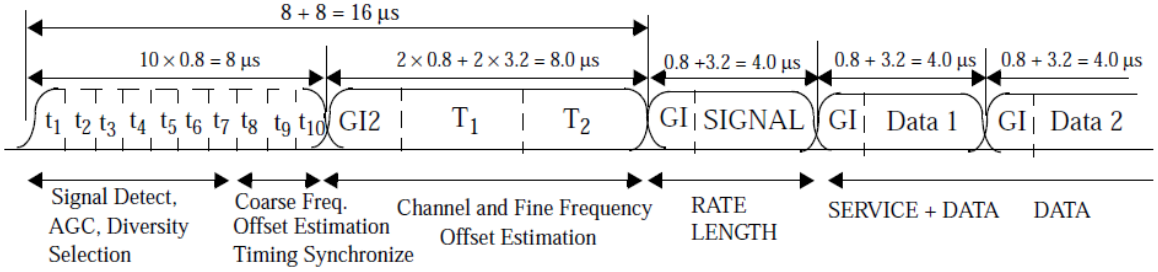
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

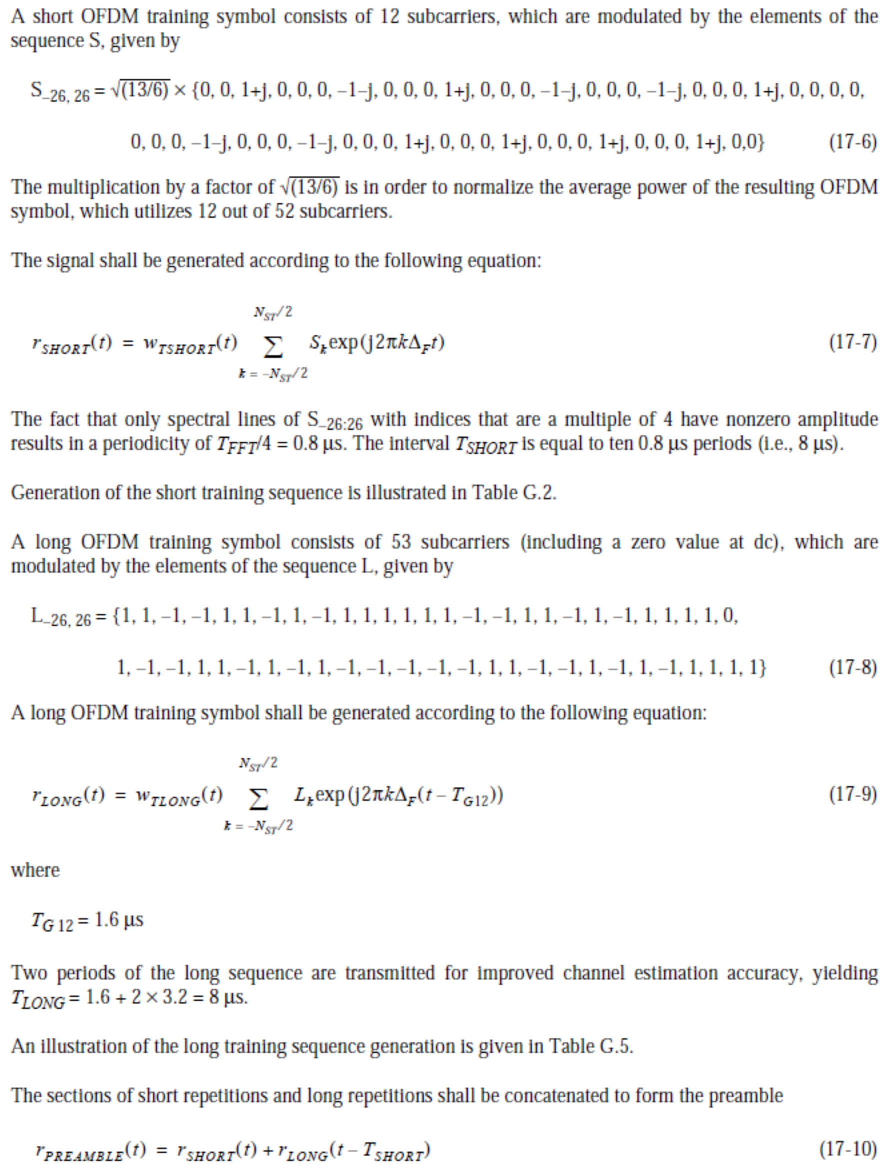
The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the “circular prefix” used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ (17-4) In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 24 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \left\{\begin{matrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{matrix}\right\}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \qquad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \qquad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ μs. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \qquad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F(t - T_{G12})) \qquad (17\text{-}9)$$

where

$T_{G12} = 1.6$ μs

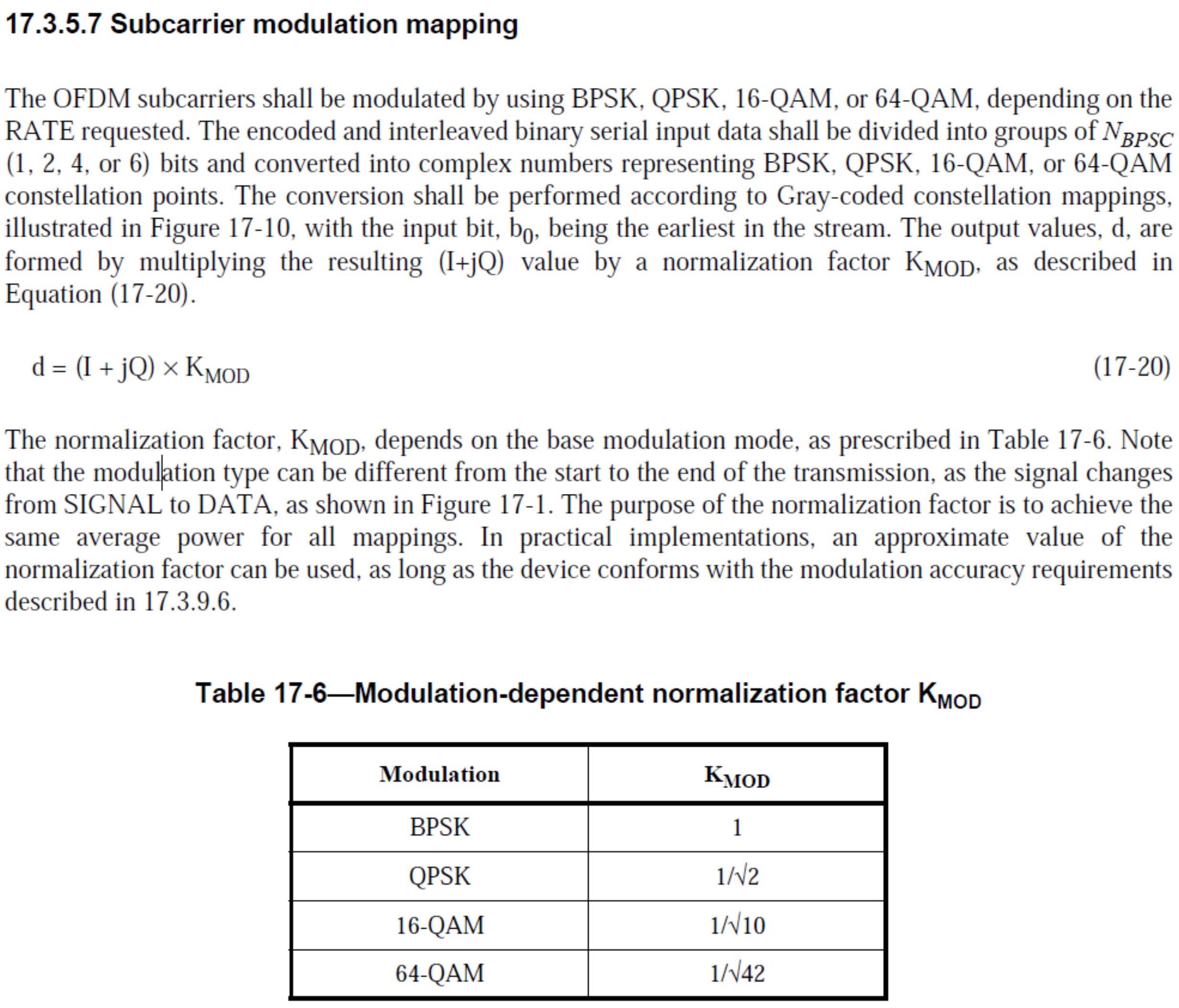
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ μs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \qquad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 24 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \tag{17-25}$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

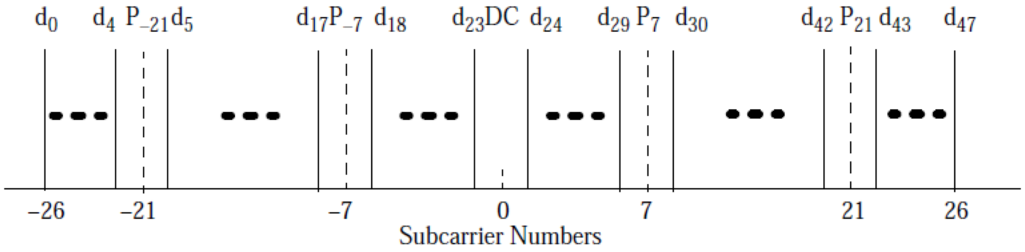


Figure 17-11—Subcarrier frequency allocation

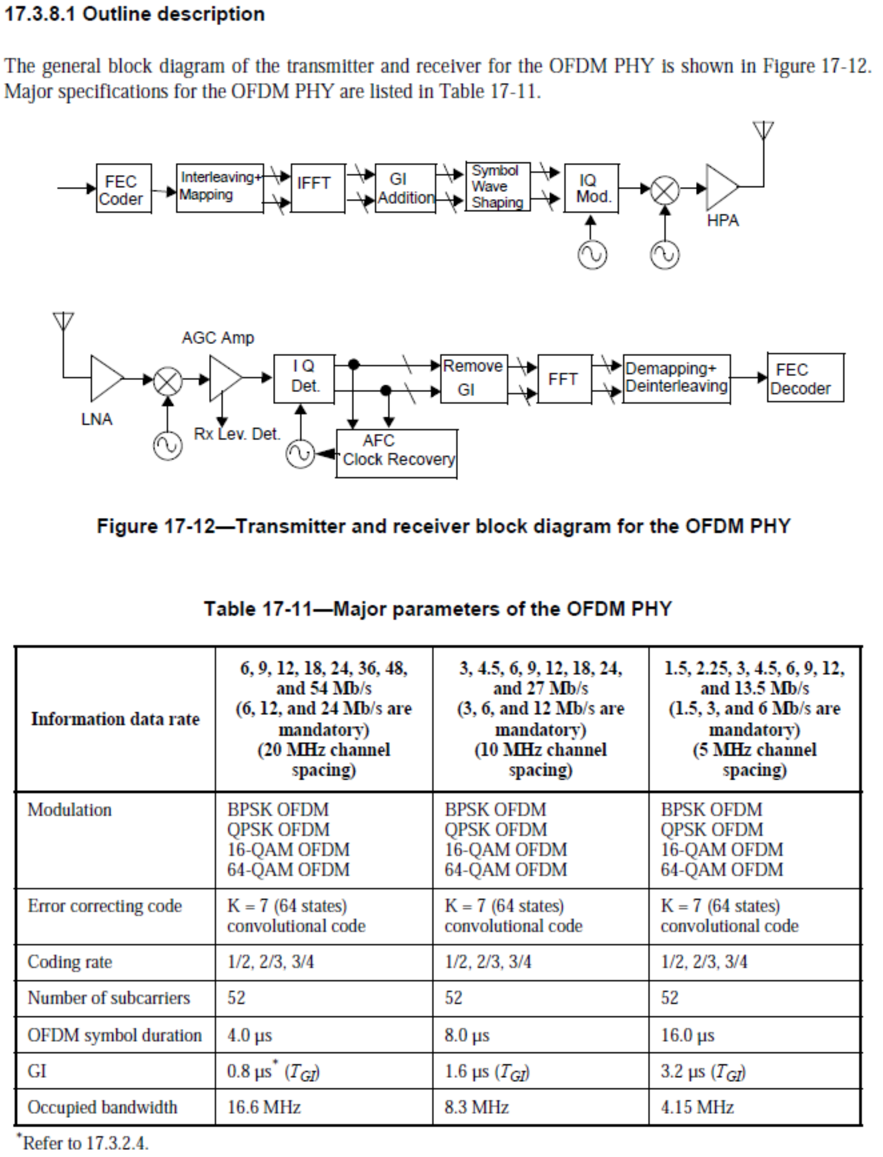
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \tag{17-26}$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

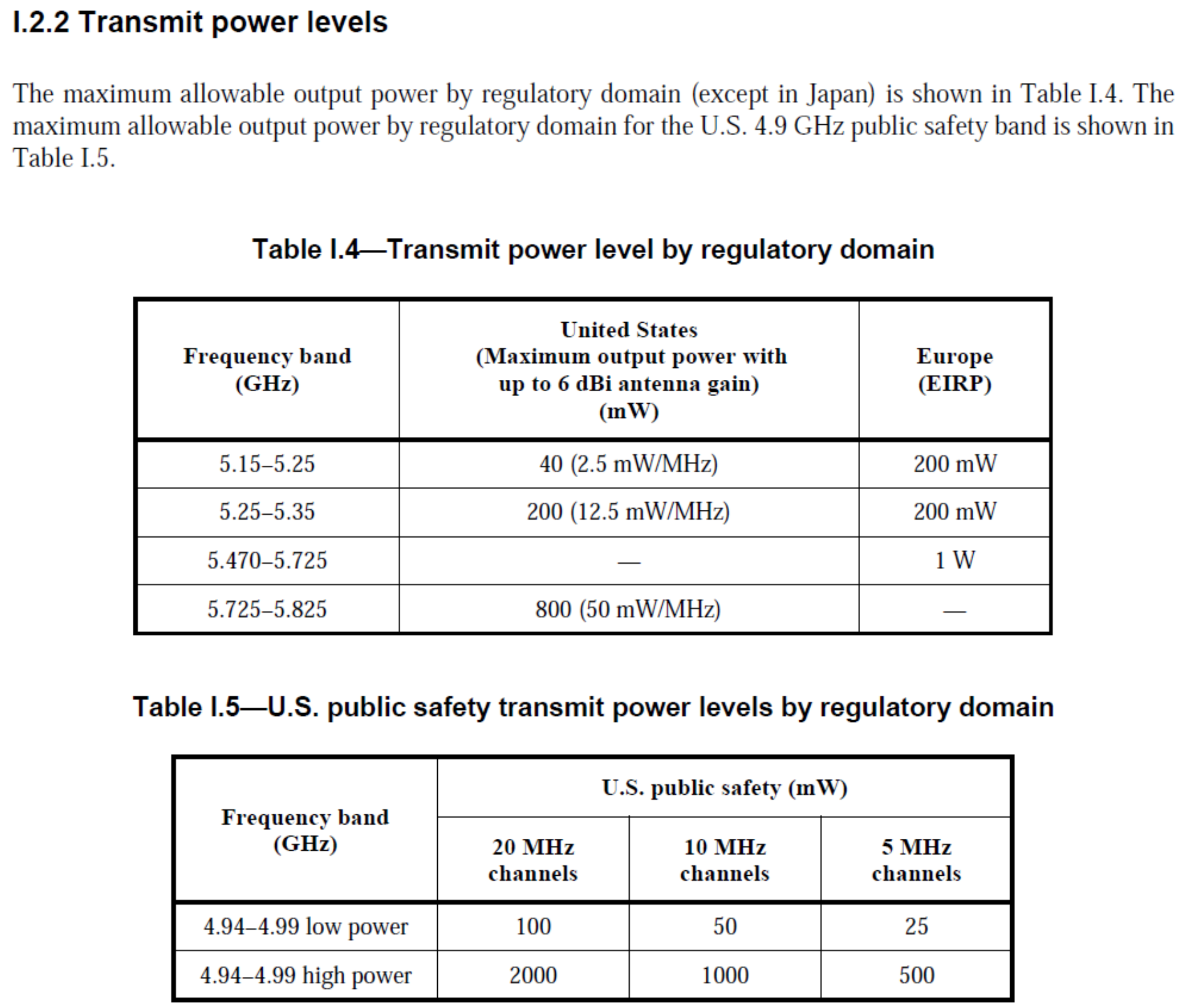
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs
GI	0.8 μs* (T_{GI})	1.6 μs (T_{GI})	3.2 μs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


<h3>I.2.2 Transmit power levels</h3>

<p>The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.</p>

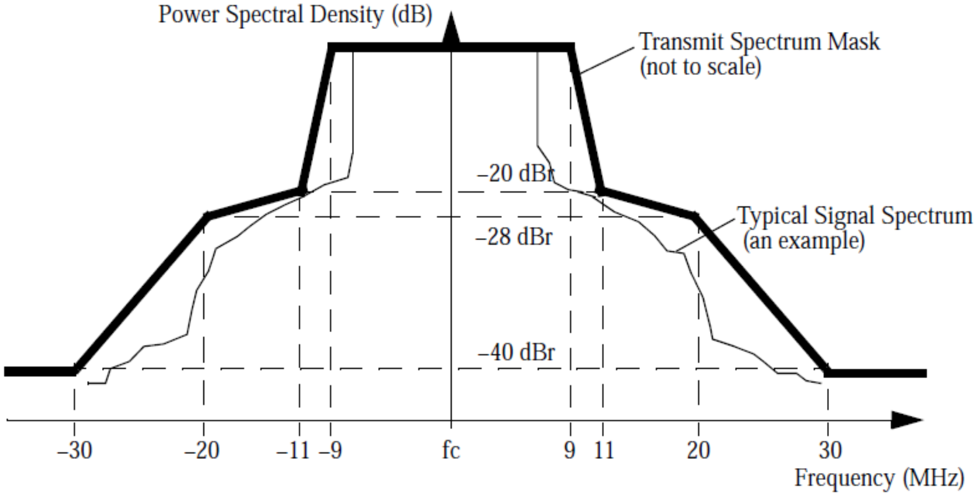
<p>Table I.4—Transmit power level by regulatory domain</p>

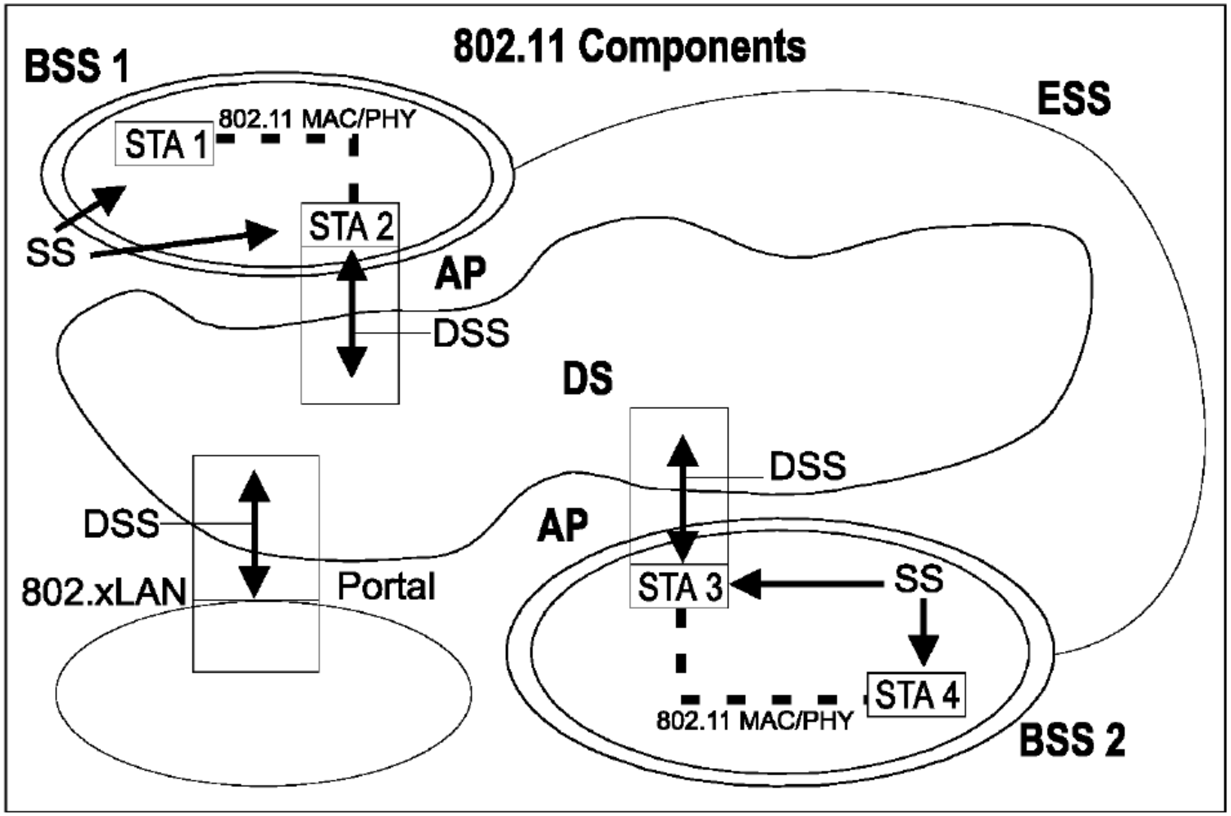
<table>
<tr><th>Frequency band (GHz)</th><th>United States (Maximum output power with up to 6 dBi antenna gain) (mW)</th><th>Europe (EIRP)</th></tr>
<tr><td>5.15–5.25</td><td>40 (2.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.25–5.35</td><td>200 (12.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.470–5.725</td><td>—</td><td>1 W</td></tr>
<tr><td>5.725–5.825</td><td>800 (50 mW/MHz)</td><td>—</td></tr>
</table>

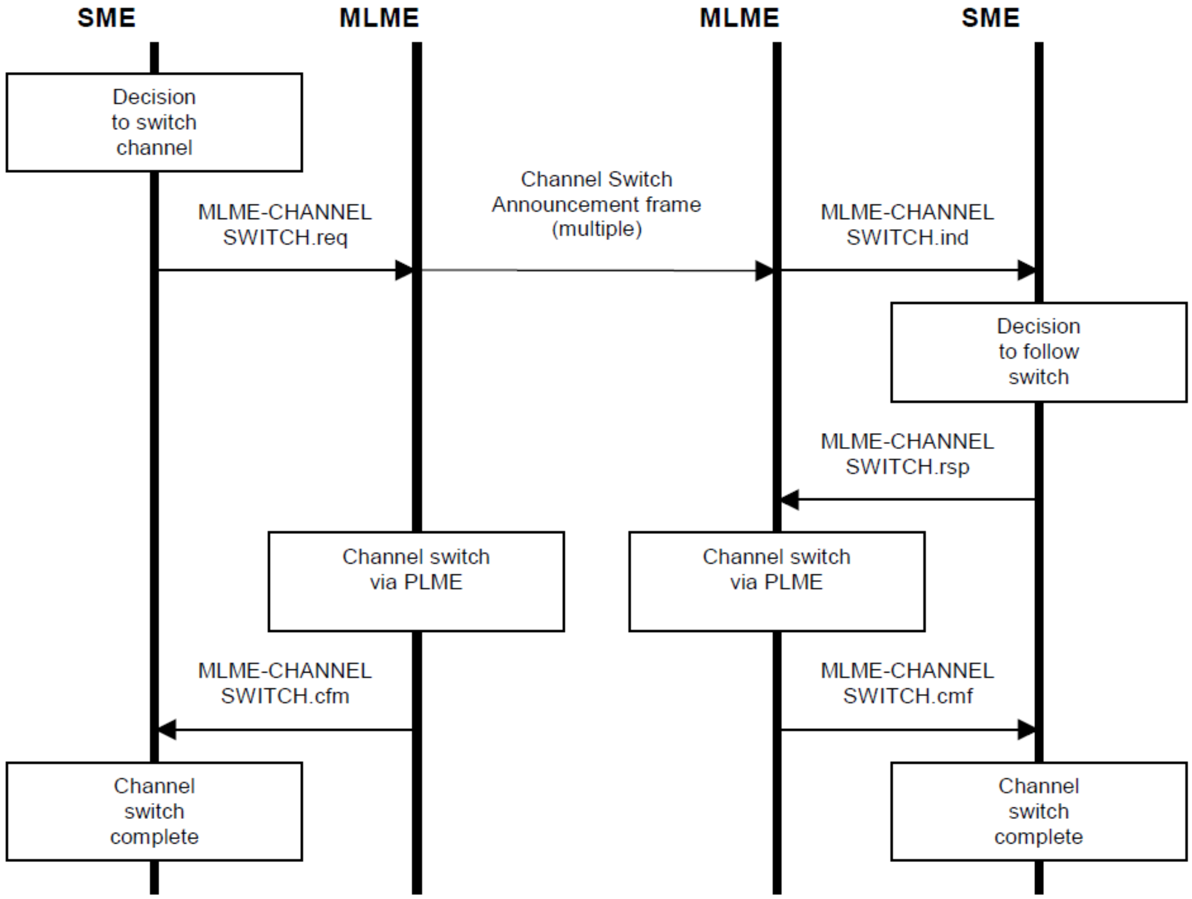
<p>Table I.5—U.S. public safety transmit power levels by regulatory domain</p>

<table>
<tr><th rowspan="2">Frequency band (GHz)</th><th colspan="3">U.S. public safety (mW)</th></tr>
<tr><th>20 MHz channels</th><th>10 MHz channels</th><th>5 MHz channels</th></tr>
<tr><td>4.94–4.99 low power</td><td>100</td><td>50</td><td>25</td></tr>
<tr><td>4.94–4.99 high power</td><td>2000</td><td>1000</td><td>500</td></tr>
</table>

<p>See, e.g., 802.11-2007 § I.2.2</p>
</td></tr>
</table>

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.  **Figure I.1—Transmit spectrum mask** See, e.g., 802.11-2007 § I.2.3

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 5-7—Complete IEEE 802.11 architecture** See, e.g., 802.11-2007 Figure 5-7

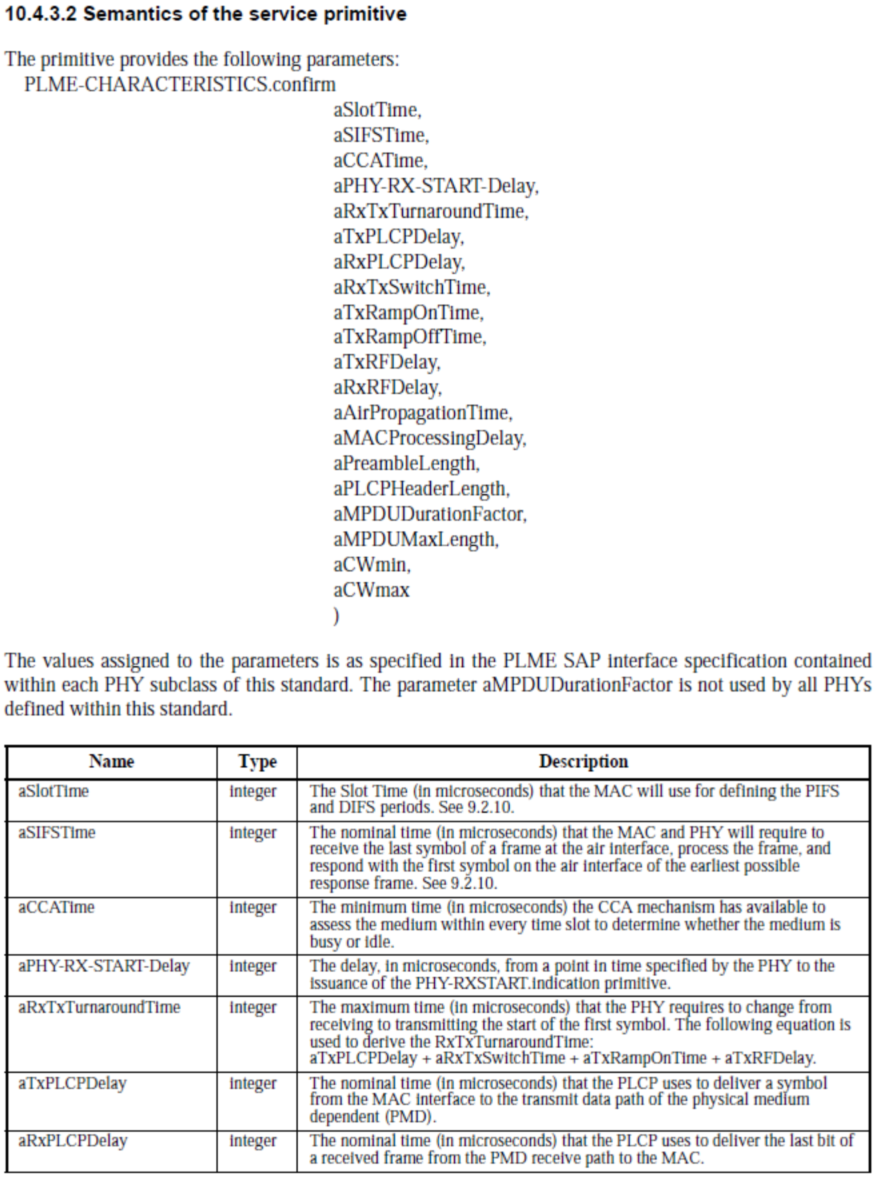
Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 24 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[24.4] a filter having an input coupled to the output of the first down-converter and the output of the second down-converter, and in accordance therewith, the filter receives the first and second down-converted signals.	802.11-2007 discloses “a filter having an input coupled to the output of the first down-converter and the output of the second down-converter, and in accordance therewith, the filter receives the first and second down-converted signals.” See, e.g.: **1.1 Scope** The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 **5.1.1 How WLAN systems are different** Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. **5.1.1.1 Destination address does not equal destination location** In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. **5.1.1.2 Media impact on design and performance** The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS “service guarantees” within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made. **5.1.1.3 The impact of handling mobile STAs** One of the requirements of IEEE Std 802.11 is to handle *mobile* as well as *portable* STAs. A *portable* STA is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* STAs actually access the LAN while in motion. For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects. Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA’s receiver will always be powered on. See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3 **5.2 Components of the IEEE 802.11 architecture** The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA. See, e.g., 802.11-2007 § 5.2 **5.2.3 Distribution system (DS) concepts** PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required. Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different. Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation. The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs. An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs. See, e.g., 802.11-2007 § 5.2.3 **5.3.2 DSS** The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities. The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture. See, e.g., 802.11-2007 § 5.3.2 **5.4.4.1 TPC** Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs’ power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 **7.3.2.20 Channel Switch Announcement element** The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20 **10.3.11 Spectrum management protocol layer model** The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). … The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11



10.4.3.2 Semantics of the service primitive

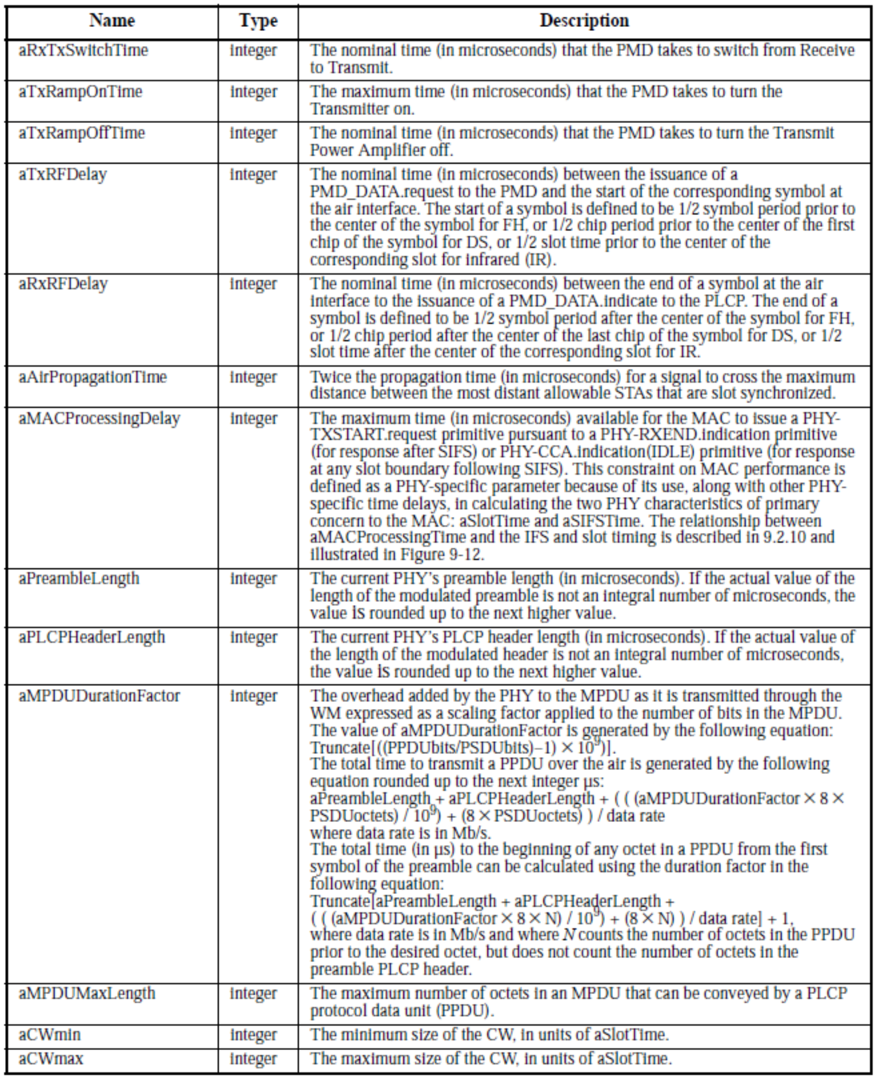
The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm
aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,
aMACProcessingDelay,
aPreambleLength,
aPLCPHeaderLength,
aMPDUDurationFactor,
aMPDUMaxLength,
aCWmin,
aCWmax
)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007

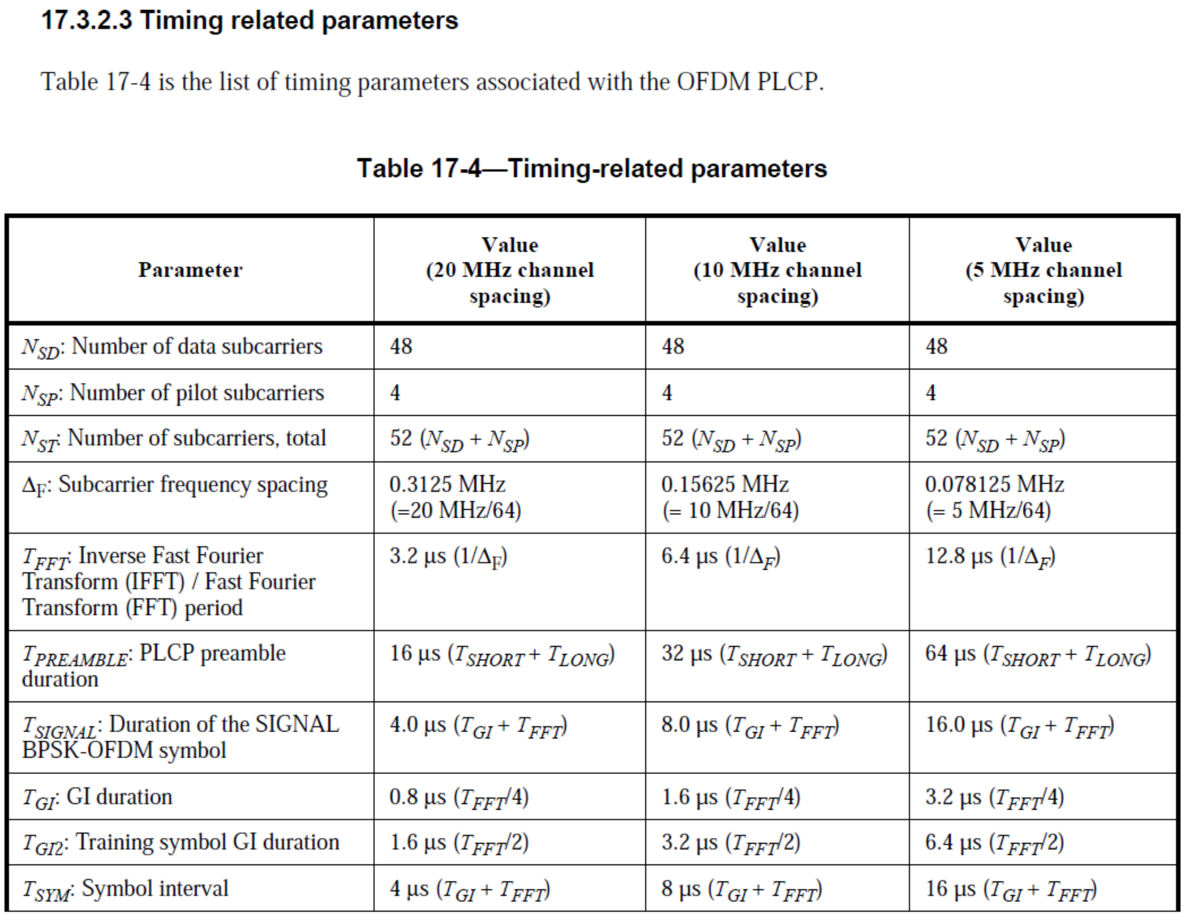


Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY’s preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY’s PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

See, e.g., 802.11-2007 § 10.4.3.2

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. The OFDM system also provides a “half-clocked” operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J. The OFDM system also provides a “quarter-clocked” operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J. See, e.g., 802.11-2007 § 17.1 **17.3.2.1 Overview of the PPDU encoding process** The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure: a) Produce the PLCP Preamble field, composed of 10 repetitions of a “short training sequence” (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a “long training sequence” (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (*NDBPS*), the coding rate (R), the number of bits in each OFDM subcarrier (*NBPSC*), and the number of coded bits per OFDM symbol (*NCBPS*). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of *NDBPS*. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to “puncturing pattern”) to reach the desired “coding rate.” Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of *NCBPS* bits. Within each group, perform an “interleaving” (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of *NCBPS* bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting “complex baseband” waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1

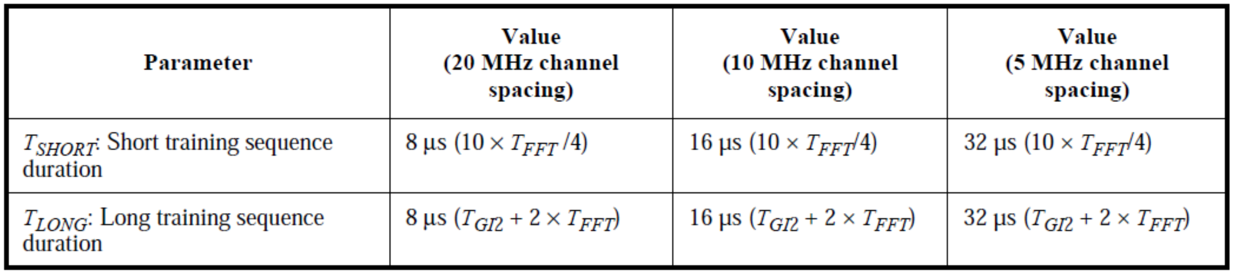
Claim 24 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	

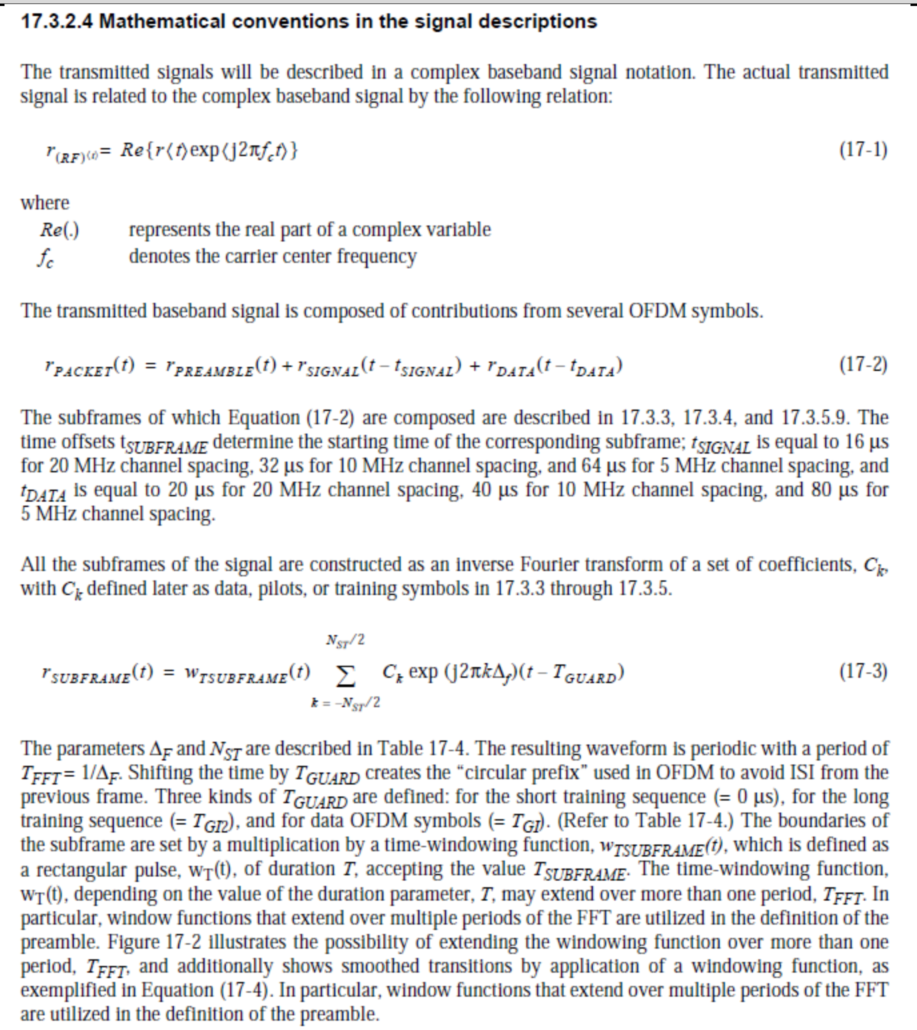
17.3.2.3 Timing related parameters

Table 17-4 is the list of timing parameters associated with the OFDM PLCP.

Table 17-4—Timing-related parameters

Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
N_{SD}: Number of data subcarriers	48	48	48
N_{SP}: Number of pilot subcarriers	4	4	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)	6.4 µs ($1/\Delta_F$)	12.8 µs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 µs ($T_{SHORT} + T_{LONG}$)	32 µs ($T_{SHORT} + T_{LONG}$)	64 µs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)	8.0 µs ($T_{GI} + T_{FFT}$)	16.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)	1.6 µs ($T_{FFT}/4$)	3.2 µs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 µs ($T_{FFT}/2$)	3.2 µs ($T_{FFT}/2$)	6.4 µs ($T_{FFT}/2$)
T_{SYM}: Symbol interval	4 µs ($T_{GI} + T_{FFT}$)	8 µs ($T_{GI} + T_{FFT}$)	16 µs ($T_{GI} + T_{FFT}$)

<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>

<table>
<tr><th>Parameter</th><th>Value
(20 MHz channel spacing)</th><th>Value
(10 MHz channel spacing)</th><th>Value
(5 MHz channel spacing)</th></tr>
<tr><td>T_{SHORT}: Short training sequence duration</td><td>8 µs (10 × T_{FFT} /4)</td><td>16 µs (10 × T_{FFT}/4)</td><td>32 µs (10 × T_{FFT}/4)</td></tr>
<tr><td>T_{LONG}: Long training sequence duration</td><td>8 µs (T_{GI2} + 2 × T_{FFT})</td><td>16 µs (T_{GI2} + 2 × T_{FFT})</td><td>32 µs (T_{GI2} + 2 × T_{FFT})</td></tr>
</table>
See, e.g., 802.11-2007 § 17.3.2.3
</td></tr>
</table>

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)(t)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} \qquad (17\text{-}1)$$

where

$Re(.)$	represents the real part of a complex variable
f_c	denotes the carrier center frequency

The transmitted baseband signal is composed of contributions from several OFDM symbols.

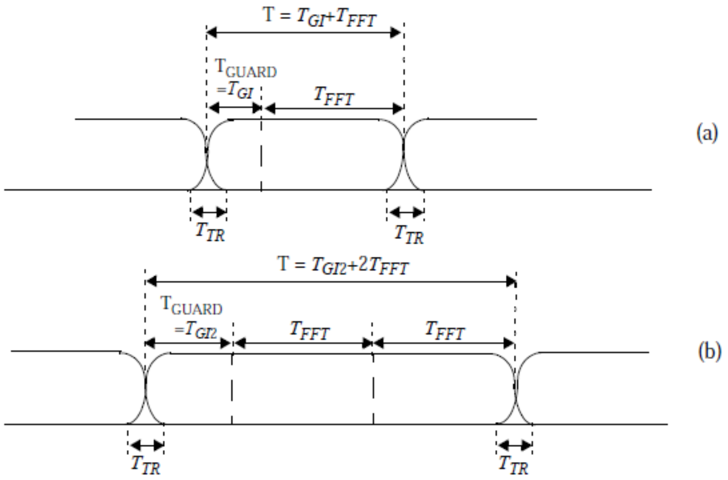
$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \qquad (17\text{-}2)$$

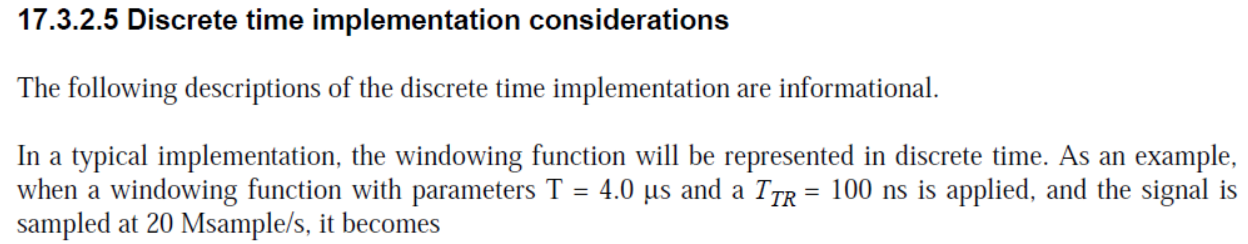
The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 µs for 20 MHz channel spacing, 32 µs for 10 MHz channel spacing, and 64 µs for 5 MHz channel spacing, and t_{DATA} is equal to 20 µs for 20 MHz channel spacing, 40 µs for 10 MHz channel spacing, and 80 µs for 5 MHz channel spacing.

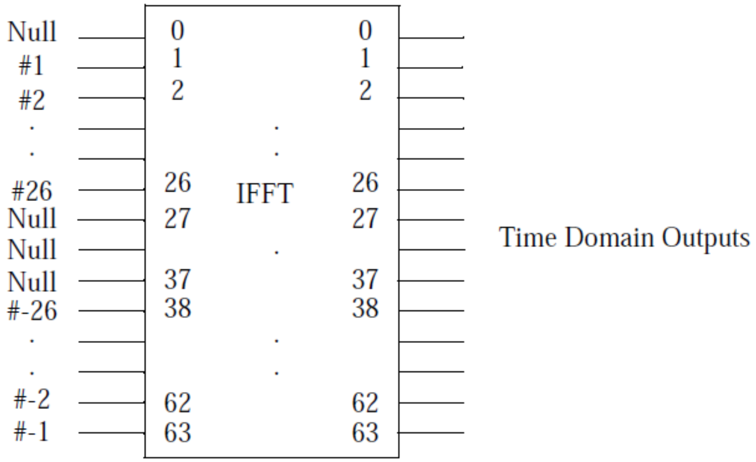
All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

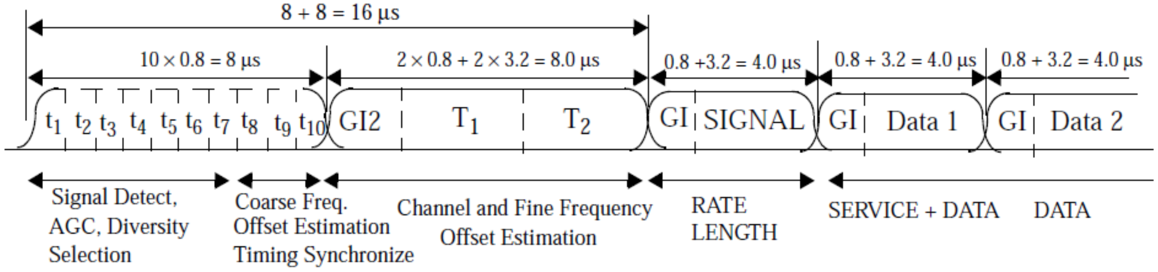
$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \qquad (17\text{-}3)$$

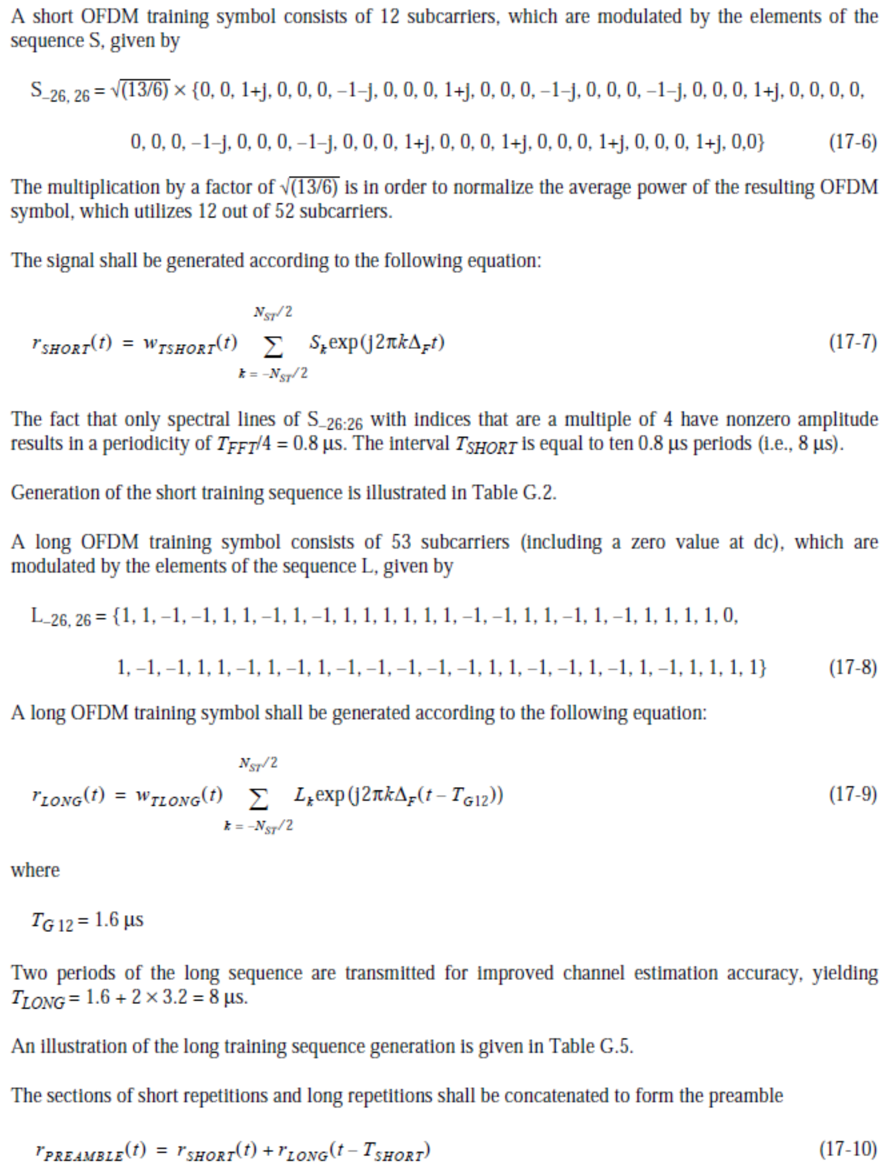
The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (17\text{-}4)$ In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 17-2. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.  **Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period** See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **17.3.2.5 Discrete time implementation considerations** The following descriptions of the discrete time implementation are informational. In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 µs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	$w_T[n] = w_T(nT_S) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & \text{otherwise} \end{cases}$ (17-5) The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.  **Figure 17-3—Inputs and outputs of inverse Fourier transform** See, e.g., 802.11-2007 § 17.3.2.5

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.  **Figure 17-4—OFDM training structure** Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.



A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26,\,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (17\text{-}6)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (17\text{-}7)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ µs. The interval T_{SHORT} is equal to ten 0.8 µs periods (i.e., 8 µs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (17\text{-}8)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (17\text{-}9)$$

where

$T_{G12} = 1.6$ µs

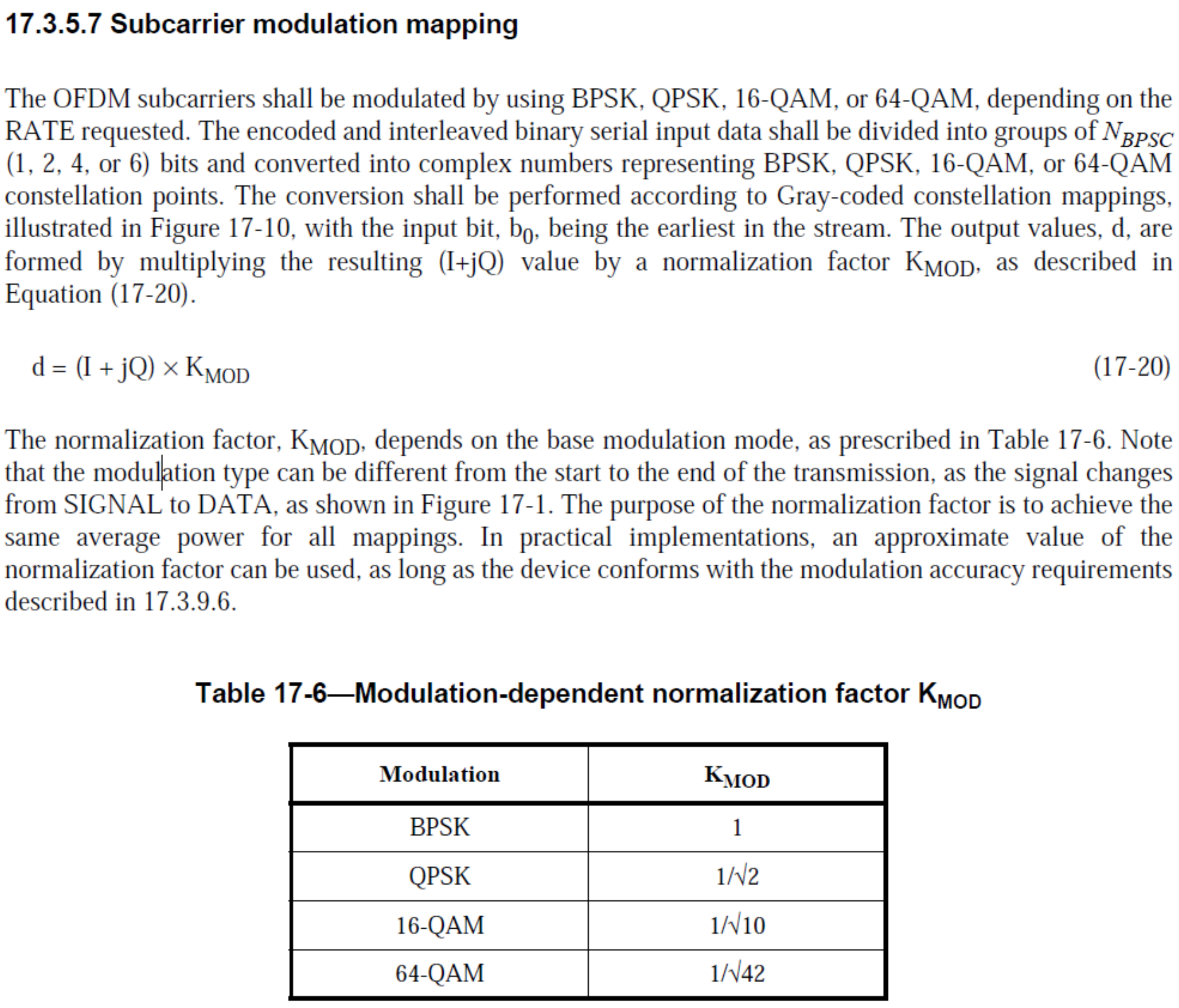
Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ µs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (17\text{-}10)$$

See, e.g., 802.11-2007 § 17.3.3

<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (17-20).

$$d = (I + jQ) \times K_{MOD} \qquad (17\text{-}20)$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 17-6—Modulation-dependent normalization factor K_{MOD}

<table>
<tr><th>Modulation</th><th>K_{MOD}</th></tr>
<tr><td>BPSK</td><td>1</td></tr>
<tr><td>QPSK</td><td>$1/\sqrt{2}$</td></tr>
<tr><td>16-QAM</td><td>$1/\sqrt{10}$</td></tr>
<tr><td>64-QAM</td><td>$1/\sqrt{42}$</td></tr>
</table>

See, e.g., 802.11-2007 § 17.3.5.7
</td></tr>
</table>

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k + N_{SD} \times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{17-21}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t - T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t - T_{GI}))\right) \tag{17-22}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases} \tag{17-23}$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{17-24}$$

The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,\ 1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,\ -1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,\ -1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (17\text{-}25)$$

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

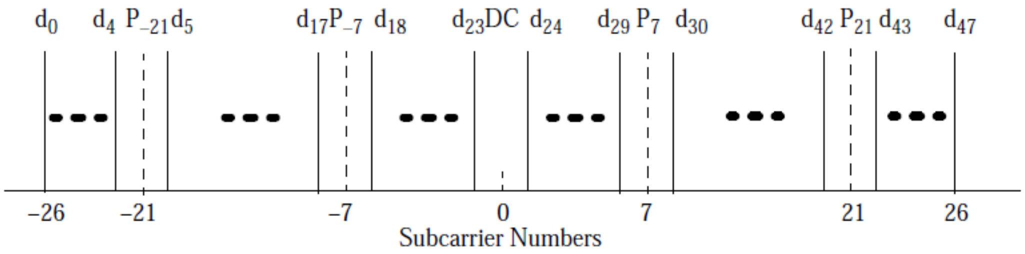


Figure 17-11—Subcarrier frequency allocation

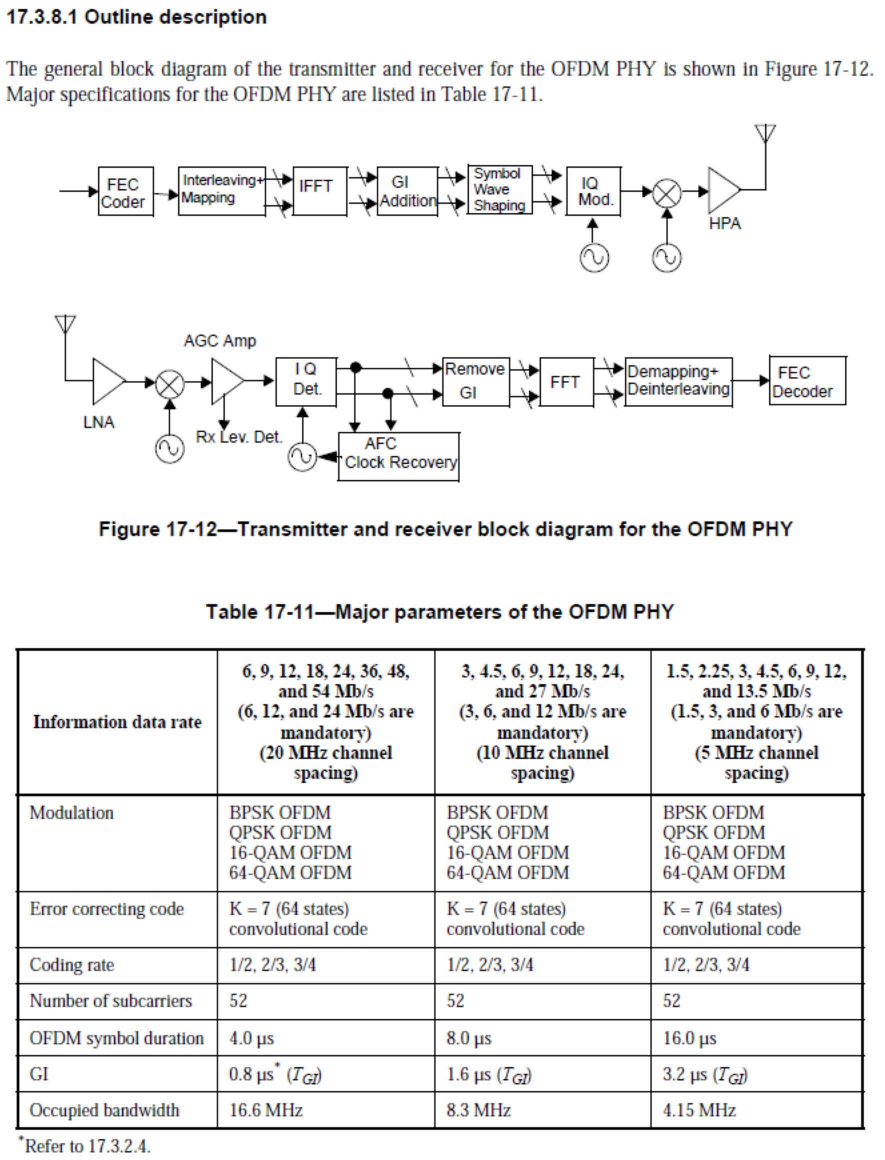
The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (17\text{-}26)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

Claim 24 of the ’802 Patent	**Prior Art Reference – 802.11-2007**
	See, e.g., 802.11-2007 § 17.3.5.9

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007



17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.

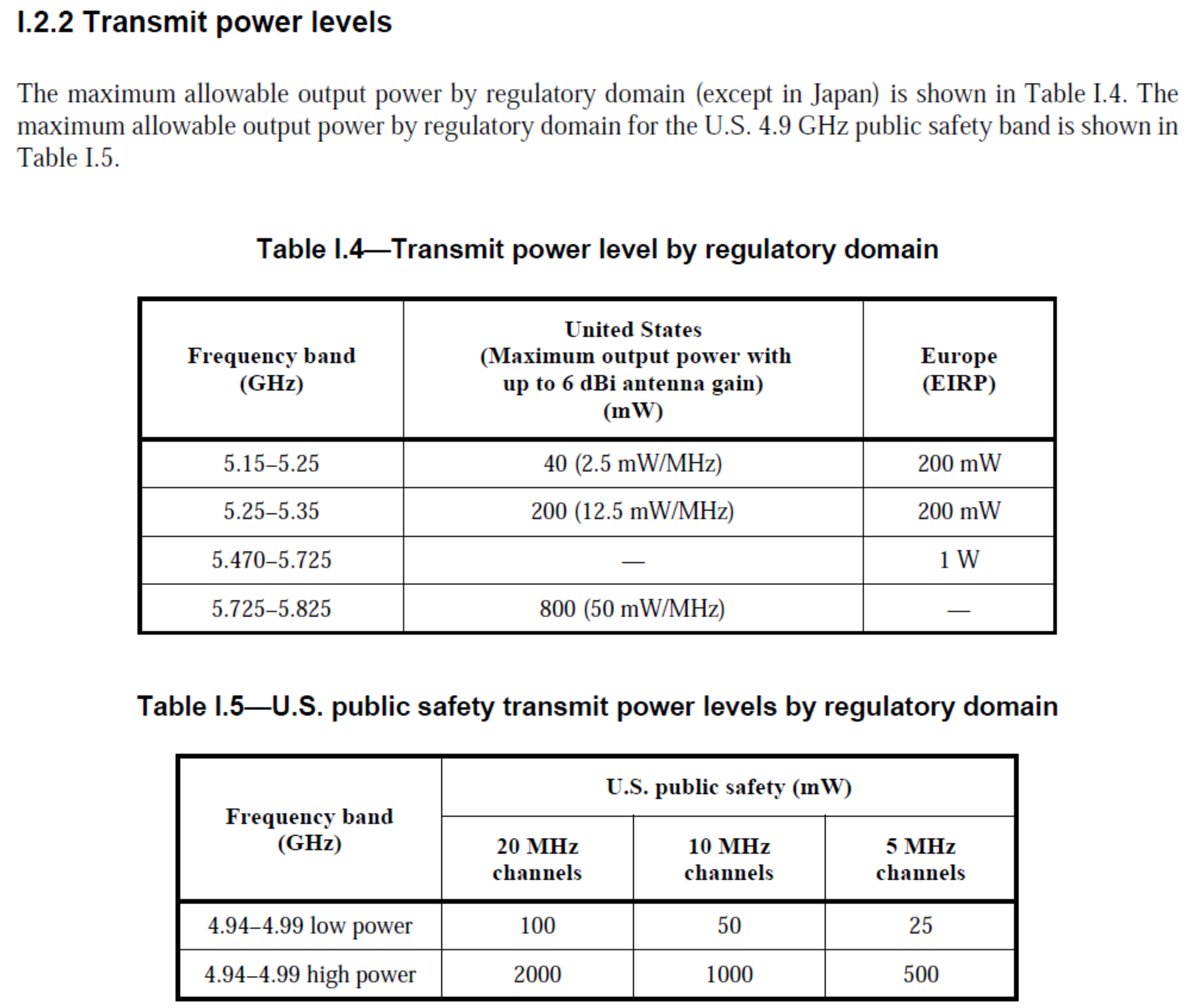
Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY

Table 17-11—Major parameters of the OFDM PHY

Information data rate	**6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)**	**3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)**	**1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)**
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Number of subcarriers	52	52	52
OFDM symbol duration	4.0 µs	8.0 µs	16.0 µs
GI	0.8 µs* (T_{GI})	1.6 µs (T_{GI})	3.2 µs (T_{GI})
Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz

*Refer to 17.3.2.4.

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1 **17.3.8.3.1 Operating frequency range** The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported. See, e.g., 802.11-2007 § 17.3.8.3.1 **17.3.9.1 Transmit power levels** The maximum allowable transmit power by regulatory domain is defined in Annex I. See, e.g., 802.11-2007 § 17.3.9.1 **17.3.9.6.2 Transmitter spectral flatness** The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step. See, e.g., 802.11-2007 § 17.3.9.6.2

<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


I.2.2 Transmit power levels

The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.

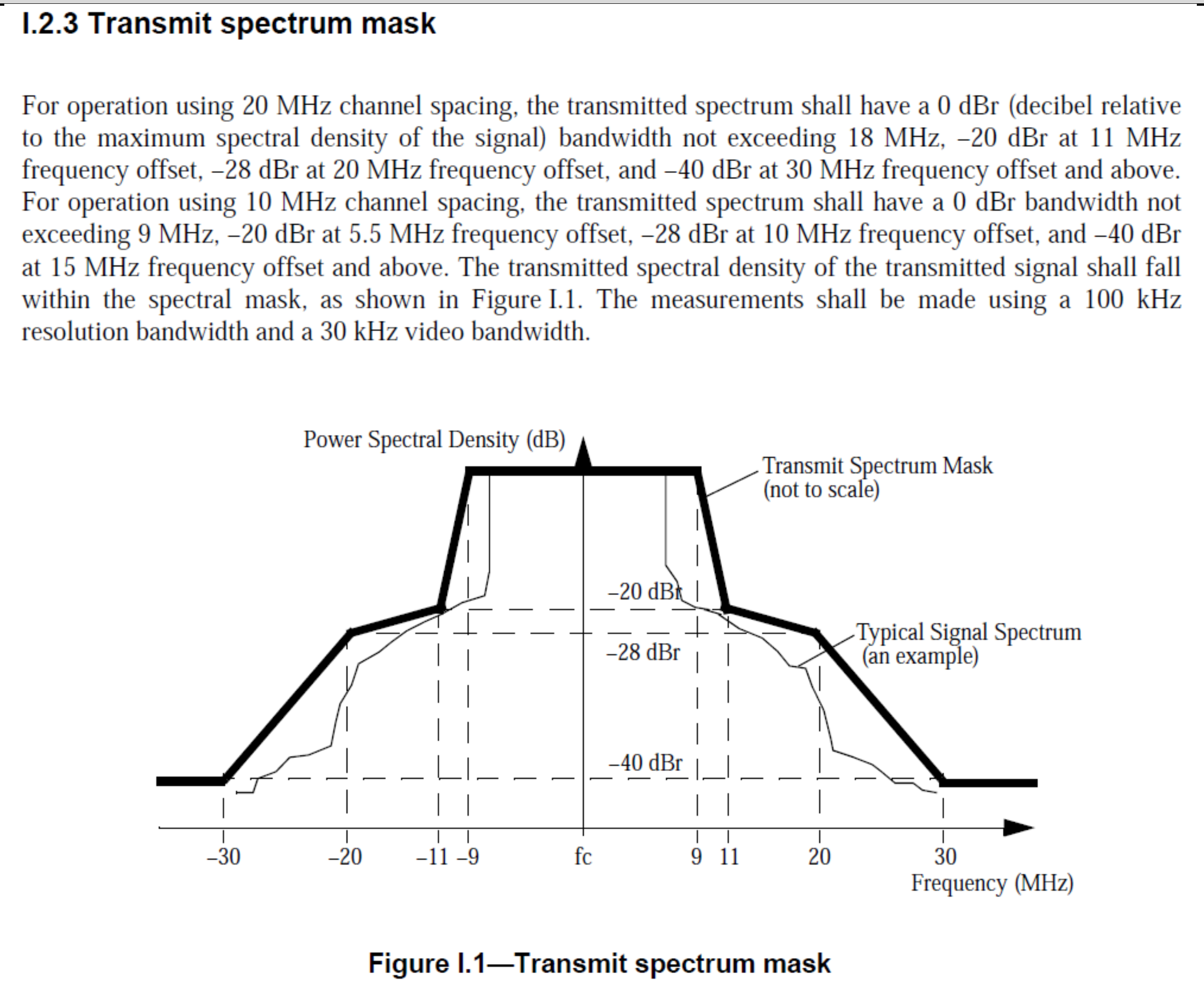
Table I.4—Transmit power level by regulatory domain

<table>
<tr><th>Frequency band (GHz)</th><th>United States (Maximum output power with up to 6 dBi antenna gain) (mW)</th><th>Europe (EIRP)</th></tr>
<tr><td>5.15–5.25</td><td>40 (2.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.25–5.35</td><td>200 (12.5 mW/MHz)</td><td>200 mW</td></tr>
<tr><td>5.470–5.725</td><td>—</td><td>1 W</td></tr>
<tr><td>5.725–5.825</td><td>800 (50 mW/MHz)</td><td>—</td></tr>
</table>

Table I.5—U.S. public safety transmit power levels by regulatory domain

<table>
<tr><th rowspan="2">Frequency band (GHz)</th><th colspan="3">U.S. public safety (mW)</th></tr>
<tr><th>20 MHz channels</th><th>10 MHz channels</th><th>5 MHz channels</th></tr>
<tr><td>4.94–4.99 low power</td><td>100</td><td>50</td><td>25</td></tr>
<tr><td>4.94–4.99 high power</td><td>2000</td><td>1000</td><td>500</td></tr>
</table>

See, e.g., 802.11-2007 § I.2.2
</td></tr>
</table>

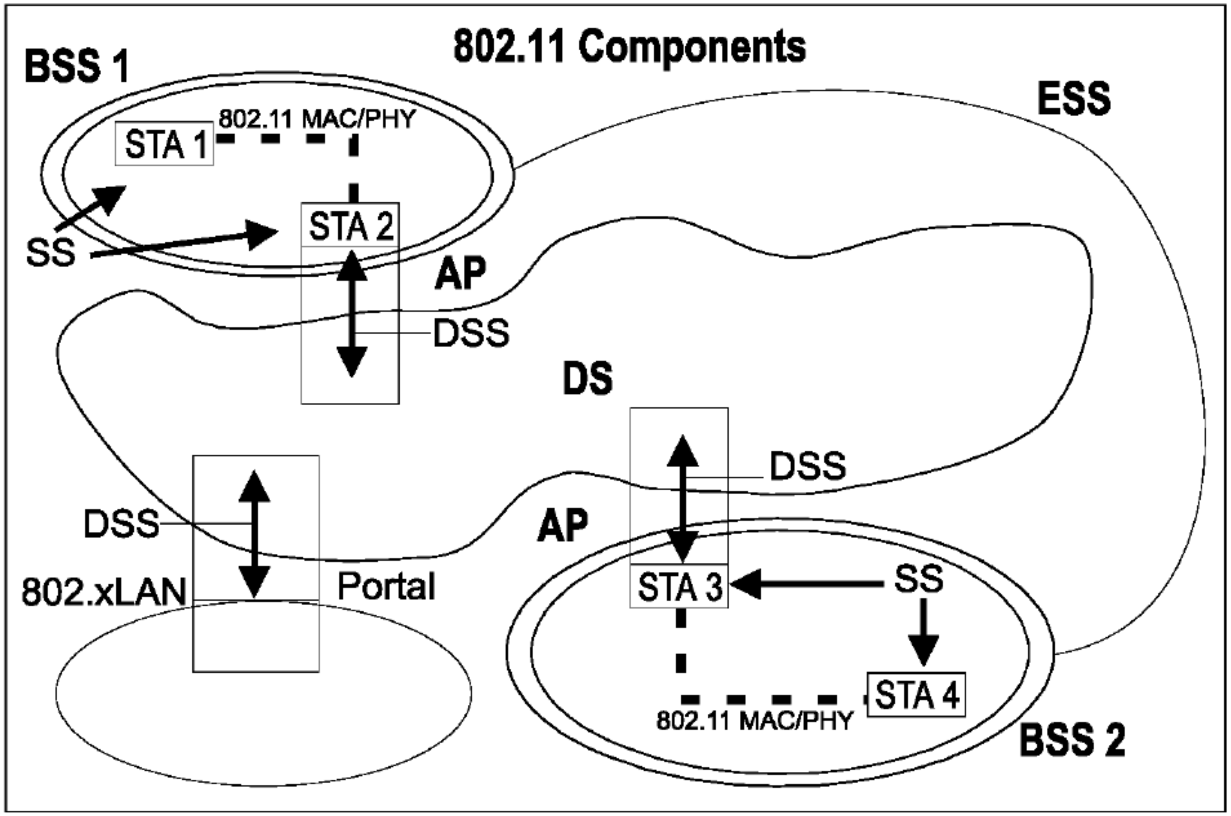
<table>
<tr><th>Claim 24 of the ’802 Patent</th><th>Prior Art Reference – 802.11-2007</th></tr>
<tr><td></td><td>


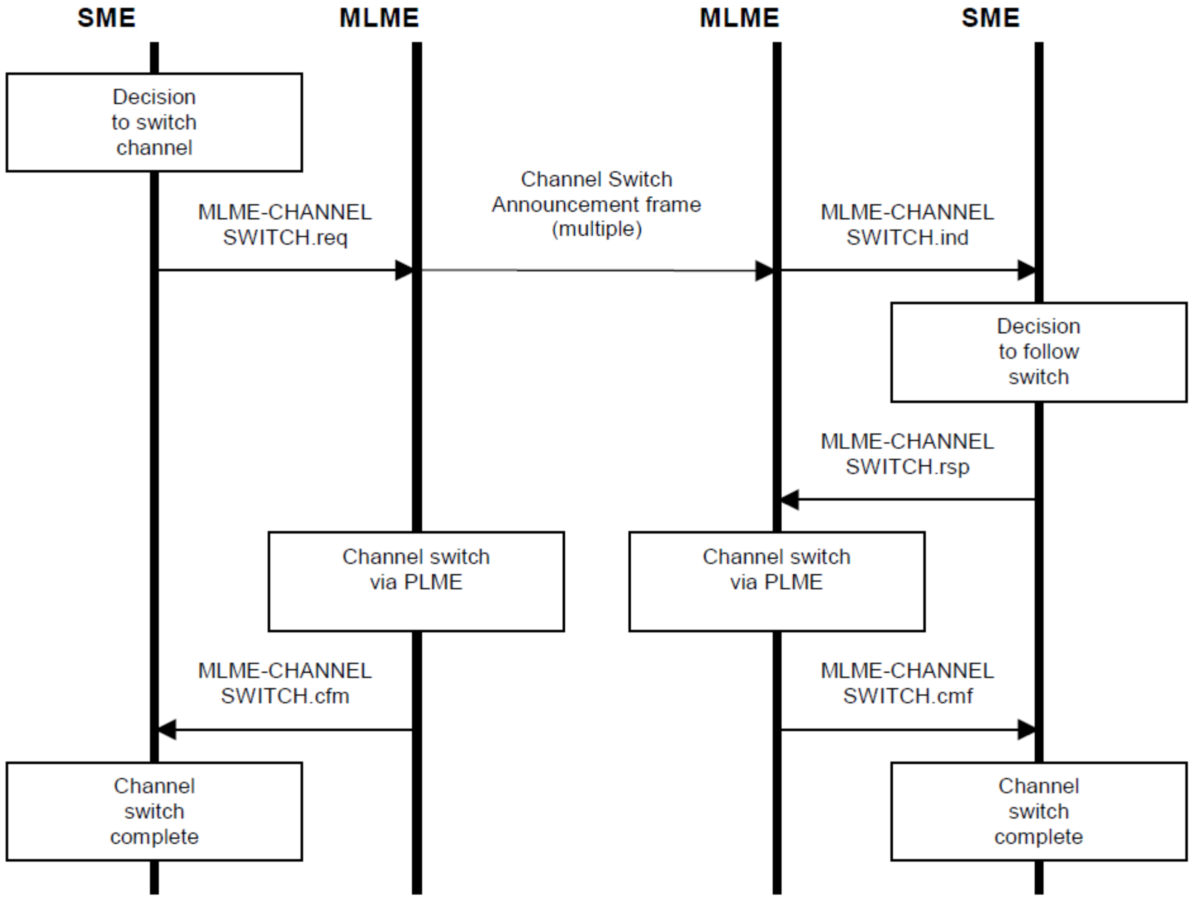
I.2.3 Transmit spectrum mask

For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

Figure I.1—Transmit spectrum mask

See, e.g., 802.11-2007 § I.2.3
</td></tr>
</table>

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 Figure 5-7—Complete IEEE 802.11 architecture See, e.g., 802.11-2007 Figure 5-7

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	 **Figure 10-6—Channel switch** See, e.g., 802.11-2007 Figure 10-6 Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-

Claim 24 of the ’802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.